PROFESSIONAL PAPERS

ON

INDIAN ENGINEERING.

VOL V.—1868.

EDITED BY

MAJOR J G MEDLEY, RE, Assoc Inst. CE,

PRINCIPAL THOMASON C E COLLEGE, ROORKEE

ROORKEE:

PRINTED AND PUBLISHED AT THE THOMASON COLLEGE PRESS.

CALCUTTA THACKER, SPINK & Co BOMBAY THACKER VINING & Co

MADRAS GANTZ, BROTHERS LONDON SMITH, ELDER & Co

1868.

JAMES JOHNSTON SUPERINTENDENT

PREFACE TO VOL V

IN concluding another Volume of these Papers, it is gratifying to state that I continue to receive assurances of the increasing utility of the publication to the Department and the Profession at large The Subscription List is in a satisfactory condition so far as numbers are concerned, it would be still more so, if all subscribers would pay up regularly.

Vol I is now entirely out of print, but as the demand for back Volumes continues, a new edition has been put to press, and will be ready before long

No **22**, being the First Quarterly No of Vol VI, will be issued on the 1st February, and the price will be, as before, Rs 14, to those who pay in advance before that date,—*afterwards* Rs 4 per number, or Rs 16 for the Volume.

J. G M

INDEX TO VOL V

LIST OF PLATES

ENGRAVINGS

ERRATA, VOL V

Page 41, line 13, from bottom,

for, first "b_1," *read*, "b"

Page 42, in case 23,

for "32," *read* "22"

Page 43, in case 24, General formula,

for "$2rh$," *read* "rh"

in case 26,

for "rh," *read* "r^3h"

Page 45, in case 31, General formula,

for "b^2," *read* "b_1^2"

Page 46, line "11,"

for "$\frac{1}{3}ab$," *read* "$\frac{1}{3}\overline{ab}$"

line 14, equation 21,

for "$b_1 - 3\ (\frac{1}{2}q)\ b_1$," *read* "$b_1 - 3\ (\frac{1}{2} - q)\ b_1$"

line 15 and 17,

for "b," *read* "b_1"

Page 48, line 1,

for "W," *read* "W_1"

lines 3 and 21,

for "b," *read* "b_1"

line 11,

for "47," *read* "42"

line 25,

for "angle of repose," *read* "complement of the angle of repose"

line 27,

for "even," *read* "except"

line 29,

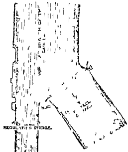
for "40°," *read* "$53\frac{1}{2}$°"

Page 154, line 9 from top, *for* "4 feet 6 inches," *read* "1 foot 6 inches"

No CLXXI

HEAD WORKS—GANGES CANAL.

The works at Myapore, the head of the Ganges Canal, consist of a Dam thrown across a branch of the Ganges, called the Kunkhul channel, at a point about three-quarters of a mile below the town of Hurdwar, which is connected on its right flank by a curved revetment wall with a Regulating Bridge (shown in the engraving) across the mouth of the canal, a line of ghâts and revetments, securing the flank of the bridge on its up-stream side This point is the real head of the Ganges Canal, and it was from here that the actual excavation of its channel commenced



The Dam, which is 517 feet in width between its flanks, is pierced in its centre by 15 openings of 10 feet wide each, which are connected with the flanks by overfalls

The Regulating Bridge has 10 bays or openings of 20 feet wide and 16 feet high, each bay being fitted with gates and the necessary apparatus for opening or closing them

The canal supply is regulated at the bridge by decreasing the openings to the necessary extent, and allowing the surplus water to pass off through the dam, during heavy floods the water is entirely shut off from the canal and allowed to flow down the Kunkhul channel, the dam being thrown open for the purpose.

The high road from Roorkee to Dehra *viâ* Hurdwar passes over the Myapore regulating bridge

The cost of these works amounted to £9,000

No CLXXII

LIGHT-HOUSES

Abridged from a Report on Light-houses, and the various apparatus employed for their illumination By LIEUT.-COLONEL ALEXANDER FRASER, R E, C B.

IT is not my purpose to make a long story about the ancient system of lighting a coast by means of coal or wood-fires, but I may as well mention here, that the last coal-light of England, that of St. Bees, was only extinguished in 1822, and the famous Tower of Cordouan, at the mouth of the Gironde, in France, on a rock which is covered 10 feet at high-water, commenced in A D. 1584, and completed in 1610, had, up to 1727, a lantern of masonry in which was burnt a coal-fire It was not till the end of the last century, that Teulère applied to this grand monument, the most beautiful light-house in the world, parabolic reflectors (of which he is said to be the inventor), and to these succeeded in 1822, about the time the parabolic reflectors were taking possession of St Bees in England, instead of the coal-fires, a dioptric apparatus, on the system proposed by M Augustin Fresnel, showing a revolving-light with eclipses every minute. This shows that France was far ahead of us in the science of light-house illumination, and she seems to me to maintain her *general* precedence in this respect to this day, having (in 1861) one light-house for every 12 miles of coast line, while England has only 1 for 14, and Scotland and Ireland, for 39½ to 34½ miles, respectively

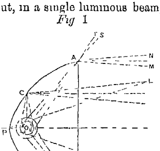
I will now shortly describe the two apparatus, Catoptric and Dioptric,

by means of which the rays from the source of light are distributed to the horizon in the direction desired

Catoptric Apparatus.—Catoptric apparatus at present in use is composed of one or more parabolic reflectors, each illuminated by a single lamp with a double current of air (said to have been invented by Argand) fed in Europe generally by Colza oil. These reflectors are of two sorts,—the one formed by the revolution of a parabola about its axis, the other by the revolution of a parabola round a vertical axis passing through its focus. *Figs* 1 and 2, *Plate* I, show a reflector of the first kind, and *Fig* 3 that of the second kind, while *Figs* 4, 5 and 6 give the manner of disposing reflectors to form a revolving or fixed light. The kind called Sideral Apparatus, shown in *Fig* 3, was invented by Bordier-Marcet.

It is easily seen, from an inspection of *Fig* 1, that the reflector gives out, in a single luminous beam, the greater part of the rays emanating from the focus O of the paraboloid, all those, indeed, contained in the angle OAPB, save the loss due to the absorption of the metallic surface and by the occultation caused by the wick of the lamp. The rays emanating directly from the flame, comprised in the angle AOB, diverge and form a luminous cone, the upper half of which is, for light-house purposes, useless. If the focal lamp could be reduced to a point, all the rays reflected would be parallel to the axis, and the transverse section of the beam ejected would be, at all distances, equal to the greatest section of the reflector. But this is not the case. The dimensions of the source of light are much out of proportion to those of the reflector, and each point of the surface reflects a conical beam whose divergence is greater as the reflecting point is nearer the focus, and the flame larger. The beam sent out from the reflector is not, therefore, cylindrical but conical. Again, the luminous rays are not equally distributed throughout the cone, which may be easily observed by following the track which they pursue after being reflected.

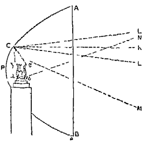
Fig 1



Let *uxyz*, *Fig* 1, be the horizontal section of the flame The rays which are most divergent in the horizontal plane are those which, tangent to this circumference, meet the reflector in P, and the angle LPK represents the horizontal divergence of the apparatus The extreme rays *z*A, *u*A, are reflected as the lines AM, AN, which form with the axis equal angles, also equal to *z*AO, OA*u* The angle of divergence of these rays is equal to MAN In the same manner may be determined the value of divergence produced at any point C of the reflector This divergence is precisely equal to the angle which is contained by the tangents drawn to the circumference of the flame In the horizontal plane, beyond the point where the lines AN, BN′ meet the lines PL and PK, the angle LPK includes all the rays reflected, to the right and left is an angular space, comprised between the lines LP and S*z*, or KP and S′*x* in which the rays emanate directly from the lamp, and lastly, in the angles SAT, S′BT′ we find but a portion of those rays which diminish from the lines AS, BS′, till they become nothing in AT and BT′. We can thus follow out any of the luminous rays in any plane.

Take, for example, the vertical plane. Let APB be the section of the reflector, *ayzu* that of the flame, and O the focus of the paraboloid The ray *z*M, drawn from the point *z* normal to the parabola, marks the limit of the divergence of the reflected rays below the horizontal plane, and the normal *u*N is that of the reflected rays above the same plane. A point such as G in the upper part of the reflector sends all the rays emanating from the flame to the right of the line OG below the horizon, and reflects all those to the left of OG above the horizon The first are comprised in the angle LGK = OG*z*, the second in the angle L′GK = OG*x*. The inverse effect is produced from all points below the focus.

Fig 2



The divergence which is formed in the horizontal plane, and below it, is useful, for, if it diminishes the intensity of the light, it has the effect of expanding the light over a good surface, but it is different with rays sent out above the horizon, which are lost In regard to other

LIGHT-HOUSES.

Fig 1

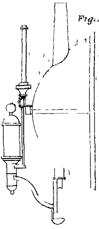


Fig 1 Side Elevation with lamp drawn for preparing light
Fig 2 Front Elevation with lamp in focus

Fig 2

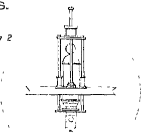


Fig 5

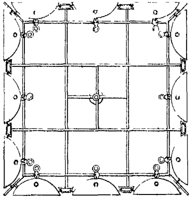


Fig 3

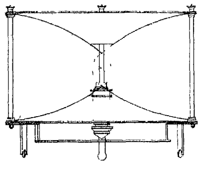


Fig 6

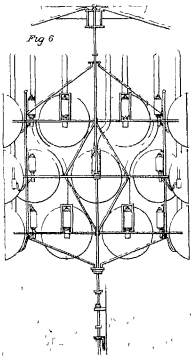
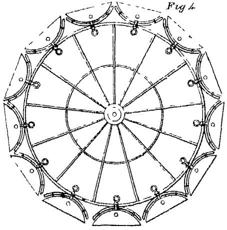


Fig 4



LITHO T.C.PRESS

matters, in order to get the greatest advantage of a light of this kind, it is necessary that the most intense part of the beam should be directed as a tangent to the horizon, and that the most brilliant section of the flame should be in the focus of the paraboloid This disposition of the flame has, besides, the effect of sending more of the rays below than above the horizontal plane

When the apparatus is elevated very much above the level of the sea, it is inclined so that its axis may become a tangent to the horizon, but in most circumstances this height is not such as to render such an inclination necessary, for in these cases the tangent is practically horizontal

Reflectors have, however, the advantage of being lighter and less expensive than lenticular apparatus, and may be employed under such circumstances as the following —

1st —For lighting narrow passages, or giving direction to a channel

2nd —To strengthen, in a particular direction, a light whose power is sufficient on the rest of the sea horizon.

3rd —For floating lights

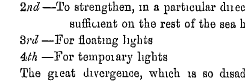
4th —For temporary lights

The great divergence, which is so disadvantageous to a light on shore, is advantageous on a light ship when not in a state of rest.

Sideral Apparatus —In the catoptric apparatus of the second kind, called in France "*l'appareil sidéral*," the luminous rays are uniformly distributed on the entire sea horizon

If the lamp were a luminous point, the only rays lost, except by absorption, are those situated in the space between the horizontal plane passing through the focus, and the conical surface formed by the revolution of a line OM round the vertical axis OP, but, as in reflectors of the other kind, the loss is greater, having regard to the dimensions of the flame This apparatus, however, can only be of small dimensions, and gives but a feeble light In France they are generally used in small portable lanterns which are hoisted on a wooden scaffolding.

Fig 3

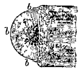


The reflectors used in the best light-houses are made of sheet copper, plated in the proportion of 6 ounces of silver to 16 ounces of copper They are moulded by hand to the paraboloidal form The ordinary burners used are one inch in diameter, and the focal distance generally adopted, 4 inches The maximum luminous effect of the reflectors ordinary employed in fixed lights is generally equal to about 350 times the effect of the unassisted flame which is placed at the focus, while for those employed in revolving lights, which are of larger size, it is valued at 450 The size of the former are generally of 21 inches aperture, and the latter 24, and their cost from £32 for the former, to £43 for the latter The lamp, with sliding carriage usually employed to carry the burner, costs about £6

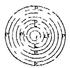
Reflectors are liable to lose much of their reflecting power when their polish has been deteriorated, or if they are not taken the greatest care of It is only necessary, for one of these faults to become at all considerable, to reduce the light one-fifth, but in their best state they absorb nearly half (·444) of the light incident on them

The following figures show a form of metallic mirrors, combined with cata-dioptric prisms and lens of glass (called holophotes) invented by Mr Thomas Stevenson, and first applied by him to the Horsburgh Light in the Malacca Straits in 1851—

Holophotal apparatus with lens



b Spherical mirror
p Cata dioptric prism
L Lens



but this is more of an adaptation (and a very expensive one, for the Alguada Reef Light apparatus on this system, and lantern, cost £3,500) of a reflector to the dioptric system, than having anything to do with the pure catoptric system which I have been describing

Dioptric system —The property which convex lenses possess of refracting, very nearly parallel to their axis, all rays emanating from the *foci*, has caused them to fulfil an analogous office to that of parobolic reflectors, but being required of large dimensions, it was found that such a lens in one piece would absorb a considerable amount of the

rays from the great thickness in the middle, that deviations, more or less great, were caused by bubbles, striæ, or difference of density in the great thickness of glass, and that they were of such a weight that it was not practicable to arrive at a good arrangement of apparatus

Without reference to maritime lights, Buffon is said to have had an idea of the solution of the problem by suggesting lenses in échelon, but he proposed that they should be made in one piece, and it was not till 1819 that Augustin Fresnel devised, when Buffon's idea had been forgotten, lenses composed of a central part, and successive échelons, cast and worked up separately, and then solidly fastened together This profile was formed on one side by a straight line, and the centres, as well as the radii and the amplitudes of the arcs of the circles on the opposite face, were calculated so as to reduce as much as possible the spherical aberration and the thickness of the glass The profile being settled, two systems of lens naturally followed—

1*st*—By giving to it a rotation round the horizontal axis passing through the focus, the annular lens was obtained, possessing the property of uniting in one beam of parallel rays all the rays emanating from the focus as in the parabolic reflectors By placing a number of these annular lenses forming a prism with a polygonal base having for its axis the vertical passing through their common focus, which would be occupied by the flame of the lamp, and by turning the drum thus composed round the said vertical axis, the luminous beams of each face are projected successively in every part of the horizon, while in the intervals no light appears Such a light is one with eclipses

2*nd*—If the same profile be turned about the vertical axis only, it forms a cylindric surface, which has the property of distributing uniformly on the horizon all the rays emanating from the source of light at the focus, and this arrangement constitutes the fixed light

3*rd*—A third species of lens is sometimes had recourse to by placing a vertical lens outside the horizontal ones, so that rays having passed through the horizontal lens, issue from the other in the vertical beam comprised between two vertical planes The arrangement, however, of this double lens is not economical of light, but it is at times employed to vary fixed lights by flashes

The central parts, (excluding the upper and lower cata-dioptric zones), of the figures in *Plate* II, give examples of the above, *Fig* 4, being

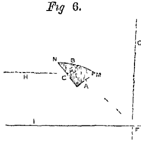
of the first kind, *Fig* 5, of the second, and *Figs* 1 and 3, to the left of the third

The height of the drum of lenses has a certain proportion to the focal distance This was at first considered to be fixed by an angle of 45°, subtended by the lens at the focus, but it has been increased, and in practice varies from 56° to 67° according to the nature of the apparatus

The rays passing below this drum of lenses, lighted uselessly the foot of the light-house, while those passing above were lost in the atmosphere Many different arrangements were imagined by Fresnel to utilize these rays by means of small lenses above, projecting the rays on mirrors which again sent them to the horizon, and by small silvered glasses below, like the sheets of a venetain blind, with a convenient inclination to catch the rays and send them in the desired direction But they were all abandoned at last for the present arrangement of cata-dioptric zones of glass of triangular section, which, by refraction and total reflection, project all the rays to the horizon

Fig 6 shows the course of a ray from the focus F. It is refracted at A in the direction AB, totally reflected at B in the direction BC, and leaves the ring in the direction CH The profile being given, it can as before, by rotation round the vertical axis FG, form a portion of the fixed light below and above the lens, or, by a similar movement round the horizontal axis, be combined with the revolving light with eclipses

Fig 6.



Figs 1, 2 and 3, *Plate* II, show the entire arrangement in the three different kinds But although these cata-dioptric rings had been employed in lights of the third order as early as 1842, it was not till 1852 that in France a light of the first order (that of Cap L'Ailly) was fitted with panels of them, and though Mr Alan Stevenson proposed in 1835 the substitution of totally reflecting prisms for the light of Inchkeith, which was the first in Scotland, and which had just been altered to the dioptric system, it was not till 1842 that a complete dioptric apparatus was erected (on the Skerryvore Lighthouse), and it was not till 1836 that the Trinity House adopted the dioptric apparatus in the Start Light, and employed Mr. A Stevenson

to superintend its erection, while it remained to a later period to Mr Thomas Stevenson to arrange a holophotally revolving light

The arrangement now became holophotal, as all the rays which were at first lost above and below the lens, or which were feebly projected towards the horizon by unsatisfactory means, were now sent in the direction desired, in the most satisfactory manner, with the simple loss of light due to the absorption of the rays in the course of refraction Experiments have shown that not much more than 55 per cent of the light incident on polished silver-plate, is reflected, while nearly 80 per cent of light is available after passing through the totally reflecting prisms

When a light is not required to illuminate the whole of the horizon, it is desirable to send to the sea the rays which would light uselessly the land For this purpose, spherical mirrors have been employed in the dead angle, to return the rays received from the focus, these rays falling upon the lens are refracted as the others For two reasons, the centres of these reflectors are placed a little higher than the focus of the lens; for, if they coincided, a great part of the reflected rays would be stopped by the lamp, and the burner and wick would be destroyed by the great heat to which they would be exposed. The great expense of substituting cata-dioptric rings with double refraction for these metallic reflectors, has prevented their being generally adopted An example of these totally reflecting mirrors, all of glass, will however be found in the Double Island Light-house* in the Gulf of Martaban, the only example in India

In catoptric apparatus, in order to arrive at a more powerful light, the number of lamps are multiplied. In lenticular apparatus, the lamp itself is increased as regards the number and diameter of the wicks The dimensions of the apparatus are regulated according to the diameter of the flame The diameters and distances apart of the wicks actually in use were determined in 1821 by Fresnel and Arago, and experience has justified their adoption

The burners of lamps of dioptric apparatus of the first order carry four concentric wicks, the second order three, the third order two, and in France, all lights with a single lamp and one wick are ranged under the fourth order But there is a large and small pattern of

* See No CX, of these papers

apparatus and lamp of the third and fourth orders, which in England have formed a fifth and sixth order

The following Table gives the dimensions and the luminous intensity of the flames, as compared with Carcel lamp of one burner Nothing would be gained by reducing the French measures to English, so I merely mention that a millimètre = 0 03937 inch —

Order		No of Wick	Diameter of flame in full development	Height from Burner	Intensity
			Mm	Mm	
1st Order		4	90	100	23
2nd „		3	75	80	15
3rd „	Large pattern	2	45	70	5
	Small „		38	65	3
4th „	Large pattern	1	30	45	1 6
	Small „		27	37	1 3

It is easy to see that it is necessary to observe a certain relation between the dimensions of the lenticular apparatus and those of the flame which illuminates it, not only to maintain within just limits the first cost, but to obtain the greatest advantage from the light produced at the focus A certain amount of divergence is in fact necessary, in order that the whole surface of the sea may be lighted, and that the flashes of revolving lights may be of a convenient duration; but if it be very great, we lose a notable part of the rays, and the intensity of the light is diminished These considerations have produced the following dimensions in France.—*See* Plate II., and the following Table (1 mètre = 39 37079 inches) —

Order		Interior diameter of drum	Height of optical arrangement: Lower part	Central part	Crown or upper part	Total height interiorly of frame inclosure.
			m.	m.	m	m
1st Order		1 840	0 539	0 980	1 001	2 590
2nd „		1 400	0 378	0 854	0 810	2 069
3rd „	Large pattern	1 000	0 278	0 660	0 593	1 576
	Small „	0 500	0 144	0 300	0 258	0 722
4th „	Large pattern	0 375	0 105	0 226	0 196	0 541
	Small „	0 300	0·084	0 180	0 157	0 433

In Great Britain there seems to be no particular system, and with exceptions of some inventions of combinations of catoptric and dioptric apparatus by the Messrs A and T Stevenson, and Mr Alexander Gordon, and the holophotal arrangement of the revolving prisms by Mr T Stevenson, almost everything which is good in either seems to have been copied from the French

The following *Figs* 7 and 8 show how the luminous rays from the flame leave the different parts of a lenticular apparatus —

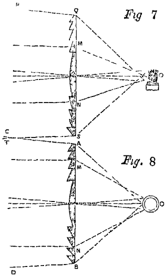


Fig 7

Fig. 8

QS, AB represent in profile and plan the section of a lens revolving, each panel being ⅛th of the whole circumference Tho focus of the optical arrangement is, in both, in O All the rays emanating from the focus, such as OM, ON, are refracted parallel to that which from the same point, passes through the axis of the lens. The others diverge more or less according to the part of the flame from which they start, and the limits of extreme divergence are given on the horizontal plane by the lines BD, AC, which are respectively parallel to the rays passing through the axis at tangents to the circumference of the flame, and in the vertical plane, the lines ST, QR, represent the extreme divergence, and these are parallel to the rays passing through the axis from the top and bottom of the flame, all the rays which have their point of departure from the top of the flame, give a plunging ray outside the lens, and all from the bottom are sent upwards When the optical arrangement is circular, instead of polygonal, the lenses are cylindrical and not annular, as said before, and the rays are sent uniformly in the horizontal plane, and they follow, in any meridional section, the same direction as in the annular section

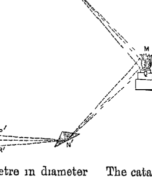
If it be desired to prevent the rays dispersing above the horizon, it is necessary to place the focal point of the apparatus a little lower than the most brilliant horizontal section of the flame; but if it be desired

to show a light at the greatest distance, the focus of the apparatus should correspond with the centre of the horizontal section of the most brilliant part of the flame

With the cata-dioptric prisms whence the rays proceed after being totally reflected, their course is calculated on a principle converse to the above.

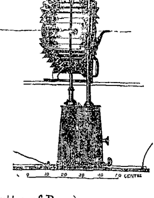
The rays from the top of the flame [see *Fig* 9] MNP, MN′P′ are directed towards the heavens, those from the centre parallel to the axis, and those from the bottom of the flame give a plunging fire

Fig 9.



For the electric light it is necessary to have special apparatus The flame given out being of such small dimensions, the mountings of the glass are not carried through the entire height of the apparatus, as they would cause complete occultation opposite them. The apparatus is also very small, not above 0 30 metre in diameter The cata-dioptric rings are calculated for a flame coincident with the focus, and the joints and projections of the profile do not follow the horizontal lines, but are according to the direction which the luminous rays take in the glass after the first refraction. *Fig* 10, presents an apparatus for this light, which is disposed as a fixed light with a view of meeting the exigencies of this new method of producing light

Fig 10



In France, St. Gobain glass is exclusively used in dioptric apparatus, and there are in France only two manufacturers (M. M. Lepaute and Sautter of Paris)

Its manufacture is said to have been much improved during the last few years, and leaves little to be desired It is said to be without color, hard, homogeneous, and it absorbs but a small part of the rays which pass through it It takes a beautiful polish, and perfectly resists the action of the atmosphere, and contains but a very small amount of bubbles and striæ Its composition is as follows —

Silica, . . .	72 1
Soda,	12 2
Lime, .	15 7
Alumina and oxide of iron, traces	
	100 00

The only manufactory in the United Kingdom is that of the Messrs Chance Brothers and Co of Birmingham I have not learnt the composition of their glass, and without seeing specimens *together* (which I have not), it is impossible to judge whether one is superior to the other or not The above three firms are the only manufacturers in the world.

The glass is cast in moulds of the size nearly required Then the rough pieces are placed in the lathes, and are roughly rubbed down by cast-iron rubbers, with sand, and the powder of pounded free stone The next step is rubbing down with emery, and the glass is then polished with rouge The cement used for fixing the glass on the lathes to undergo grinding is composed of eight parts Swedish pitch and one part of wood-ashes, heated in an iron-pot and used almost in a state of ebullition. The cement used for the adjustment of the pieces of glass which touch each other on their frame, is composed of 12 parts white-lead, one part minium or red lead, and five parts boiled linseed oil, pounded and applied liquid The lathes revolve by steam, and the lens and belts and rings, or zones, are ground to take the exact form (mathematically determined) required, and a perfect polish Each part composing one lens is made separately, and the edges are fixed together by cement as above, and in France, as in England, are mounted in frames of bronze It is desirable, in calculating the lens, to reduce the thickness of the glass as much as possible, but this is limited by the necessity of having a certain strength, by the difficulty of manufacture, and above all, as it would lead to so great expense.

Considerations of the progress which had been made in the execution

of cast glass, led, some years since, M Degrand to imagine that this mode might be applied to the lens in échelons with a view of reducing the thickness of glass, thus returning to Buffon's original idea with both a greater motive and better chance of success This had been found to answer very well in the small apparatus, but not in the larger, and the system in the present state of the glass manufacture is not probably susceptible of extension, for the reduction of the thickness of the glass is not found to compensate the dispersion of rays by irregularity of surface caused by the uncertain shrinking of the glass in the most accurately turned moulds

Range of Lights —The distance at which a light can be seen depends on its intensity, and the height above the level of the sea, or its luminous range, and its geographical range I do not intend to go into the various photometric experiments from which the following Table in regard to the first has been prepared, but merely give it as it stands, premising that the intensity given is that at the most and least favorable states (excluding fogs) of the atmosphere, and the comparison is made with a standard Carcel lamp which has a clock-work movement, and whose flame continues to increase in power for about four hours after it is lighted, after which it maintains its state permanent until the supply of oil fails —

Designation of light apparatus	Intensity in burners of the Carcel lamp		Range in nautical miles in an atmosphere				Amplitude of flash in degrees and tenths	Remark
			Most Favorable		Least Favorable			
	Fixed Light	Flash.	Fixed Light	Flash	Fixed Light.	Flash		
1st Order Apparatus								
Fixed Light . . .	630	..	39 8		9 8	.		
Light with eclipses every minute Lens 1/8—prolonged flash	60	5,075	21 8	59 8	6 8	12 7	9° 4	All these apparatus have a lamp of 4 wicks which consumes 1 6755 lbs of colza oil per hour, and whose flame is itself equal to 23 burners
Light with eclipses every 1/4 minute, . Lens 1/16—short flash, .	60	8,475	21 8	55 4	6 8	12 1	6° 0	
Fixed light varied by flashes, Moveable lens of 34° 12′,	630 190	4,000	39 8 20 4	56·8	9 8 8 2	12 3	5° 6	

Designation of light apparatus	Intensity in burners of the Carcel lamp		Range in nautical miles in an atmosphere: Most favorable		Least favorable		Amplitude of flash in degrees and tenths	Remarks
	Fixed Light	Flash	Fixed Light	Flash	Fixed Light	Flash		
2nd Order.								
Fixed Light, .	335	.	33 9		8 9			
Eclipses every minute, Lens $\frac{1}{8}$, prolonged flash,	25	2,550	16 2	52 3	5 8	11 7	9°·4	
Eclipses every $\frac{1}{2}$ minute, Lens $\frac{1}{16}$, short flash,	25	2,275	16 2	51 2	5 8	11 5	6° 0	All these apparatus have a lamp of 3 wicks which consumes 1 1028 lbs per hour, & whose flame gives an intensity of 15 burners
Fixed light varied by flashes, Moveable lens 43° 40′,	335 / 95	2,700	33 9 / 24 4	52 9	8 9 / 7 3	11 8	5 3	
3rd Order								
(Large pattern)								
Fixed light, . ..	90		24 0	.	7 3			
Eclipses of a minute, Lens $\frac{1}{8}$, prolonged flash,	7	815	10 3	41 9	4 4	10 2	8°0	
Eclipses $\frac{1}{2}$ minute, Lens $\frac{1}{12}$, short flash, .		750	10 3	40 8	4 4	10 0	5°5	All these apparatus have a lamp of 2 wicks, which consumes 385805 lbs of oil per hour, and whose flame gives an intensity of 5 burners
Flash light of 20″ without eclipses, Lens $\frac{1}{10}$,	50	470	20 2	36 7	6 6	9 4	5°2	
Fixed light varied by flashes, Moveable lens of 44° 32′	90 / 25	950	24 0 / 16 2	42 9	7 8 / 5 8	10 3	4°7	
Apparatus for lights of direction								
Lens of cast glass of 1 metre in diameter, with lamp of 1 6 burners, .	200	..	29 8		8 8		12°0	Oil 132276 lbs per hour
Lens of cut glass of 50 metres in diameter, with lamp of 1 6 burners,	300	.	33 0		8 8		9°0	Oil 132276 lbs per hour
Reflector of 0 85 m. opening with lamp of 1 6 burners,	760	.	40 9		10 0		18°0	Oil 385805 lbs per hour,
Reflector of 0 85 m opening with lamp of 1 6 burners,	550		38 1	.	9 6		12°0	Oil 132276 lbs per hour
Sideral apparatus with lamp consumes 45 grammes per hour = 1 15 burners, ..	3 5	..	7 9	..	3 7			Consumption of oil = 099207 lbs per hour

It will be observed from the above that in the fixed light, the axis presents a light of an intensity $=$ 630 burners, and this intensity is thrown all round the horizon, or the whole quantity of light $=$ 630 $\times$ 360 $=$ 2,26,800 burners, and that to form a fixed light by the catoptric system which shall produce an equal quality of light, it would be necessary to fix on a frame about 48 reflectors of the largest size, each burning 385805 lbs of oil, or $18\frac{1}{2}$ lbs per hour for the 48, against an expenditure of only about $1\frac{4}{5}$ths lbs per hour in the dioptric light.

Geographical range —It will of course be fully understood how the spheroidal form of the earth affects the height of a Light-house tower the following Table, taken from Mr Alan Stephenson's "Treatise on Light-houses," will give all necessary and practical information on the point —

H Heights in feet	λ Lengths in English miles	λ Lengths in nautical miles	H Height in feet	λ Lengths in English miles	λ¹ Lengths in nautical miles	H Heights in feet	λ Lengths in English miles	λ¹ Lengths in nautical miles
10	4 184	3 628	60	10 246	8 886	200	18 708	16 22
20	5 916	5 130	70	11 067	9 598	300	23 912	19 87
30	7 245	6 283	80	11 832	10 26	400	26 457	22 94
40	8 366	7 255	90	12 549	10 88	500	29 580	25 65
50	9 354	8 112	100	13 228	11 47	1 000	41 833	36 28

If the distance at which a light can be seen by a person on a given level be required, it is only needful to add together the two numbers in the columns of lengths λ or λ¹ (according as English or nautical miles may be sought) corresponding to those in the column of heights H, which represent respectively the height of the observer's eye and the height of the lantern above the sea When the height required to render a light visible at a given distance is required, we must seek first for the number in λ or λ¹ corresponding to the height of the observer's eye, and deduct this from the whole proposed range of the light, and opposite the remainder in λ or λ¹ seek for the corresponding number in H The Table includes a correction for mean refraction; and the formula from which the values are derived is $H = \frac{4}{7}l^2$ where H = height in feet, and l = distance in miles

Comparison of the two systems of apparatus —I have been chiefly indebted to a *Mémoire Sur L'éclairage des Cotes de France*," by M. Léonce

Reynaud, Director of the Light-house Service and Secretary of the Light Commission of France, published in 1864, by order of the Minister of Public Works, and partly to the Treatise on the "History, Construction and Illumination of Light-houses," by Mr Alan Stevenson, published in 1850, and to the Report of the Royal Commissioners on the light, &c, system of the United Kingdom, published in 1861, for most of the observations made above regarding the two systems of illumination, and those who desire to enter more deeply into the subject, I must refer to the above books I have only so far alluded to the principles of the difference of the systems to enable each one to judge for himself of the justness of the following comparison of the two systems which is summed up by M Reynaud in the first-mentioned work (which is also the latest), as follows.—

1st —The reflection on the most polished surfaces absorbs more rays than the passage across a lens of the usual thickness.

2nd —In apparatus of established dimensions, divergence in catoptric apparatus is very much greater than in the other

3rd —Dioptric apparatus enables the luminous rays to be distributed uniformly on every part of the horizon, which cannot be with catoptric apparatus, unless the reflectors are multiplied beyond measure

4th —Much more brilliant flashes can be obtained from dioptric apparatus than from catoptric arrangements

5th —The first cost of the ordinary reflecting system is less than that of the dioptric, but the annual expenditure is very much greater That is, the useful effect of dioptric apparatus is considerably above that of the catoptric

It is probable, however, that the combination of the spherical metallic reflector with the annular lens (*see* figures at page 6), called by Mr Thomas Stevenson, C E, holophotes (which are in fact modifications of the dioptric system), and applied by him to the Alguada Reef Light-house, combine some advantages on both systems when applied as a revolving-light, but in first cost it is higher than either, while there is no diminution of annual expense if compared with either The only reason it was employed by the Government of India was the fear of the single light of the dioptric system going out, while there are 16 lights in the frame of the revolving apparatus of the Alguada Reef Light-house, any one of which remaining unextinguished would still be useful

to the mariner But I think an examination of the nature of the dioptric lamps used, which I shall explain when I come to the subject of lamps, will cause all fear of any such accident happening to the single light of dioptric system to be discarded The lantern and light apparatus and revolving machine of the Alguada Reef Light-house cost £3,500, while a first order dioptric light, with 8 annular lenses giving a similar effect, would cost in France about 68,000 francs, or say £2,720, and in England about £2,872, so that while we enjoy at a higher price a light perhaps not equal, *even as a revolving light*, to the dioptric light of the same character, the materials employed are of an inferior nature, both as regards liability to deterioration and solidity of construction, while the annual cost of maintenance, and the difficulty of looking after, and keeping up the flames of 16 lamps to a proper height is, of course, greater *

However, M Reynaud remarks, that the "useful effect" of a light apparatus is deduced from the formula $\frac{L}{I+E}$, in which L designates the quantity of light transmitted, I the annual interest of the prime cost of the apparatus, E the annual expense of maintenance, comprising the consumption of oil, wicks, chimnies, and the salaries of the keepers, maintenance of apparatus and furniture, and local repairs &c From which he deduces that the dioptric arrangement is nearly *four times* as economical as the catoptric

It may also be added that the care of the single lamp of the dioptric system is much more easy for the keepers, and it follows that there is much greater likelihood of economy of light than in the catoptric system

I will conclude this part of the subject by quoting several high authorities, besides that of M Reynaud, in favor of dioptric or lenticular lights

For fixed lights, both Mr Alan and Mr Thomas Stevenson agreed that the lenticular apparatus "produces its effect by the simplest conceivable combination of the best optical agents," and the latter was of opinion that it required *eight* of the largest reflectors in use to equal the effect of *one* of the eight annular lenses in a first order revolving apparatus

M Léonor Fresnel reported in 1852 to the United States Light Commission, that very few catoptric lights, considered as lights of the

* Some of this extra cost is due, however to the extra cost of the lantern on the Scotch principle, *see* p 27.

first class, equal the lenticular lights of the same character of the *second order*, and that it would be impracticable to construct a reflector light which would equal a dioptric light of the first order

Mr Alan Stevenson stated, in his Treatise above alluded to, that "the more fully the system of Fresnel is understood, the more certainly will it take the place of all other systems of illumination for light-houses, at least in those countries where this important branch of administration is conducted with the care and solicitude which it deserves"

The American Government appointed a Commission in 1852 for the investigation of the system, which reported —That the lens, or Fresnel system of light-house illumination, is in economy, brilliancy, power, and usefulness, superior to the best reflector system in the ratio of about 4 to 1, while the cost in consumption of oil is about 1 to 4, they also recommended that the lens system be adopted as the illuminating apparatus for the lights of the United States, embracing all new lights and renewals It appears that full effect has been given to this recommendation, for, while in 1852 there were only five lens lights, there were in 1860 over four hundred

Colored lights —Colored lights are obtained by placing in front of the lamp or lens a plain colored sheet of glass, or a second lens of colored glass, or, in fixed lights, by surrounding the flame with a colored chimney The first is most commonly used in France, and the last, which seems to me the most economical and efficient, in Scotland.

Harbour and local lights, which have a circumscribed range, should generally be fixed instead of revolving, and may often, for the same reason, be safely distinguished by coloured media

The red color is obtained by salts of copper, of silver, or of gold, and the tints given by them correspond with a deep red of a fine purple, orange, red more or less deep, and carmine-rose The first of these colors is the most decided red, and that which absorbs the most rays of light when observed at a small distance, the others have the opposite properties The color obtained from the salts of copper absorbs about $\frac{8}{10}$ths, orange and red about $\frac{5}{6}$ths, of the light produced by combustion From experiments, however, made at Paris, it would appear to have been proved that at *equal intensities* the red light ranges further than white. Green is sometimes used to denote the end of a pier,

&c, but it absorbs about $\frac{1}{20}$ths of the light produced, other colors absorb much more, and have all been rejected

The coloring of lights is intended to give them a distinguishing character easily recognized, but nevertheless, in misty weather, a white light may appear red, and a green light white It follows that colored lights ought never to be shown alone It is necessary always to associate them with one or several white lights, so that the contrast may cause their nature to be appreciated Thus, in misty weather, a white light being placed near a red light, the first may assume a red color, but not to such a degree as to appear as red as the second, and if the white light is associated with a green, the red color which the first may assume is capable of appreciation with the true color of the other.

It follows from this that the lights of the first order, which at great distances are seen alone, should never be entirely red, but that without inconvenience in that case red and white flashes may be made to alternate, and that fixed red lights are not admissible, except for lights of small range (from 6 to 12 miles), and on the condition that they are placed near lights of the natural color This arrangement is often had recourse to when two lights are associated to give a course One of them is of the natural color, and illuminates all the sea horizon, the other is red, and its rays are concentrated into an angular space of 10 or 20 degrees so as to restore to it the intensity abstracted by the color

In France, the first order lights are those which illuminate the landfall (*les phares de grand atterrage*), and present the following nine different characters.—

Lights of natural color—

1st —Fixed light.

2nd —Lights with eclipses every minute,

3rd — ,, ,, ,, half ditto

4th — ,, ,, ,, scintillating light.

5th —Fixed light varied with flashes.

6th —Two fixed lights.

Lights colored—

7th —Lights of natural color varied with red flashes.

8th — ,, ,, with eclipses, with alternate flashes red and white

9th —Lights of natural color with two flashes of white succeeding a flash of red

I should be inclined to get rid of the 5th character, and put in eclipses at two minutes' interval, by which there would be greater economy of light and of the optical agent

In France, however, they use, except for short flashes of 20″ or below that, no holophotally revolving lights, where the entire flash throughout the whole height of the apparatus revolves, as in England or Scotland, but the drum and cupola form the revolving light, while the lower prisms give forth a fixed light

The French consider that a light where the eclipse is of a prolonged duration should never be entirely lost sight of, but I do not think myself there is very much force in this opinion

Oils —M. Reynaud classes them as follows, according to the qualities desired in France —

Duration of combustion in a lamp of one wick	Intensity in one lamp, in one wick	Intensity in one lamp, more than one wick	Resistance to congelation	Inferiority of price in France
Cocoanut	Olive	Cocoanut	English Colza	Baleine
Arachide	Cocoanut	Colza, French	French do	Colza
Spermaceti	Spermaceti	Do, English	Baleine	Cocoanut
French Colza	Arachide	Baleine	Olive	Arachide
English do	French Colza	Arachide	Spermaceti	Olive
Olive	English do	Spermaceti	Arachide	Spermaceti
Baleine	Baleine	Olive	Cocoanut	

In India, cocoanut oil would probably be first in all respects, except as regards resistance to congelation As regards price, French Colza oil is 122 francs the 100 kilogrammes, cocoanut oil in Calcutta may be Rs 14 per maund Taking the kilogramme = 2 2046 lbs

the franc = $10d$

the maund = 82 lbs

and the rupee = $2s$

We have the cost of the Colza oil in Paris = $5\frac{1}{2}d$ per lb

and of cocoanut oil in Calcutta = $4\frac{1}{4}d$,,

In regard to congelation, the cocoanut-oil would, except in (for India) very cold weather, be liquid, but there is not much difficulty in making it so when required

Oils of schist or petroleum are also used in the smaller orders in France, but they are said to require great care to prevent the lamps

smoking, but this done they are less expensive, and give greater brilliancy for a given amount of consumption

Lamps and Wicks —In all lamps in which Colza oil is burned the wicks are cylindrical, and placed between two currents of air to render combustion as active as possible The glass chimney is contracted at a certain height above the burner, in order to project the air against the middle and upper part of the flame

Burners with more than one wick are preferable to the others as regards economy of light, for the luminous intensities increase in a much larger proportion than the consumption of oil It is, however, in order that the burners may not be destroyed by the action of the heat to which they are exposed, necessary to cause a considerable excess of overflow of oil over that which is consumed, and this arrangement is also favorable to maintaining the flame in its normal condition It is, therefore, regulated in France that the superabundance should be thrice the consumption, and the following represents the quantity of oil passing over the burners per hour —

		Kilogrammes
For lights of the 1st order,	..	3 040
" " 2nd "	.	2 000
" " 3rd "	large pattern,	0 700
" " 3rd "	small " ..	0 100

The ordinary fountain lamp is used for lamps with one wick when the light has not to be shown all round the horizon, or in reflectors, as in *Figs* 1 and 2, *Plate* I, but where this is the case, moderator lamps are used *Fig* 4, *Plate* III, is the mechanical lamp used in Scotland for lights of the 1st order, and which is perhaps the best lamp hitherto known for 4 wicks *Fig* 5, *Plate* III, is the pressure lamp, invented by M Armand Masselin of Birmingham, and improved by Mr James Chance, which was made to meet the following conditions —"A constant and even supply of oil to the burner equal to four times the consumption, simplicity of construction, so that any unskilled mechanic can take the lamp to pieces and put it together again, freedom from liability to derangement, and an accurate fit of the various parts, so that all duplicate parts will fit equally well" These conditions appear likely to be fulfilled by this lamp, and if so, it is a lamp peculiarly fitted for India, instead of the mechanical lamp, and would be moreover cheaper than the three mechanical lamps which have to be supplied.

LIGHT-HOUSES

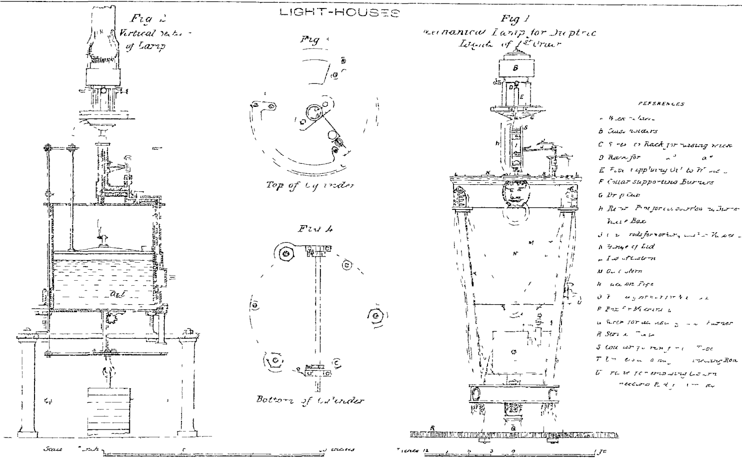


PLATE III

Cotton is only employed in France for the wicks of the apparatus called sideral, all other lamps have silk wicks, patterns of which are lodged in the Central Establishment in Paris, and, in accordance with which, all supplies are to be conformable In Great Britain, cotton is, I believe, exclusively employed for wicks All lamps have, of course, chimnies, and in the three first orders are supplied with a damper to regulate the combustion

Gaseous combustibles —Hydrogen gas is more economical than Colza oil, but it does not give a flame so brilliant at the surface as that of oil, and it is liable to produce explosions Oil gas gives a beautiful flame, but it is not economical, and does not offer more security than the other

The price of, and fear of explosions with oxygen, gas, has caused it to be rejected

The oxy-hydrogen lamp, or Drummond lamp, has been recommended many times, and has been modified more or less successfully, but the expense, and its danger and irregularity, have not admitted of its being employed practically

Magnesium —This substance, when burned in thin ribbons, gives a beautiful light, and a lamp has been invented in which the filings passing through a tube on to a flame, also give a very brilliant effect. But in either case the residuum is so heavy, that it would be impossible at present to use it in permanent lights, and moreover there would be little certainty of regularity of light from it It seems, however, an excellent substance for fire-works, or for signals from light-ships, &c

Electric light —In regard to this light which is now actually in permanent use, and may be brought more into employment for very important situations, I reserve a Report to a future date, merely remarking that it has been permanently applied in France to the two fixed lights on Cap La Hève near Havre, and I do so more as an interesting fact than as recommending it for use in India, except, perhaps, at some future period in one or two special positions. But involving, as it does, a double set of apparatus and lamps, a double set of magneto-electric machines, and a steam engine also in duplicate, I am of opinion that the administration of the light-house service must be very perfect before this light, and the means of producing it, can be adopted, and it is better at present to turn our attention in India to

the improvement of our present light-house arrangements on the system so successfully put in practice in France, rather than allow our attention to be turned to the elaboration of an expensive experiment which could only result in giving no general advantage in "useful effect" over oil, but which might be useful in particular places in exceptional circumstances, when the administration had become able to deal with it

Machines for giving rotation.—Machines for giving rotation, set in motion the mobile parts of the apparatus They are moved by weights, and their speed is regulated by a fly-wheel Usually, in France, placed at the side of the apparatus, they are put in communication with it by a cog-wheel so disposed as to be thrown in or out of gear at pleasure The rope suspending the motor-weight crosses the roof or the floor which supports the lighting apparatus in a groove contrived for that purpose, and the weight working over a roller and system of pullies descends in a vertical recess formed in one of the sides of the tower

Some new apparatus have their machine fixed in the base of the armature, which is enlarged in consequence.* The weight is about 165 lbs in existing machines of the first order, it is furnished with tackle, and it is estimated to descend at the rate of about 3½ feet per hour.

Armature.—The armature of the apparatus of the first three orders is supported by a cast hollow column which is bedded at its foot in the floor, and carries the table of the apparatus This table, formerly of wood, is now of cast-iron, the keeper gets upon it when he requires to touch the lamp The tables of the first orders are furnished with boxes in which are kept various articles required in the service.

Iron uprights, tied by ribs, start from the table, they rise to the whole height of the drum, and the circle in which they are collected at the top, serves as a *point d'appui* to the cata-dioptric panels of the crown These panels are kept in their position by screws, and are surmounted by a ring which clips the central pin in a fixed apparatus, and in a revolving apparatus carries horizontal rollers which run round a vertical tube of cast-iron fixed to the lantern In lights with eclipses, the armature is wholly or partially movable, according to the arrangement of the apparatus.

The rotary movement takes place on a carriage with vertical rollers which run between the lower plate of the moveable apparatus and that

which rests on the capital of the cast-iron column. Horizontal rollers are employed to reduce the friction. This lower plate used to be made of wrought or cast-iron, and soon wore under the action of the rollers; it is now of steel and the rollers of bronze. The wear and tear takes place chiefly on these latter works, which are more easily re-placed than the plate, though this, too, is arranged so as to admit of being renewed. The vertical rollers can be either pushed out or drawn in; they are furnished for that purpose with moveable washers encircling their axles, which can be applied at will to either face.

LANTERNS.

French Lanterns.—The French lanterns are polygonal. The table below exhibits their forms and ordinary dimensions:—

Order.	No of sides	Interior diameter between the uprights	Height of glazing, including astragals	Height of cupola including the cowl	Remarks.
1st order, . .	16	3·50 m	3·82 m	2·53 m	1 mètre=39·37079
2nd „	12	3·00 „	2·60 „	2·29 „	
3rd „ ...	10	2·50 „	1·90 „	1·88 „	
4th „	8	1·60 „	1·12 „	1·16 „	

The uprights, the ribs, and arcs of the cupola of the lanterns of the three first orders are made of iron. The uprights are cased outside by a bronze plate fixed to them by screws and tin-soldering. The horizontal astragals are in bronze. The cupola, which is single, is of sheets of copper overlapping each other on the line of the arc, rivetted and soldered at the junction. The lanterns of the 4th order being of small dimensions, are made in one piece, and simply fixed on the upper astragal. No iron is used in the construction of these small lanterns.

The ventilation of the lanterns is a very essential matter. The object is two-fold: to assist the combustion of the lamp, and to diminish the condensation which forms on the inside of the glasses of the lantern and reduces more or less the brilliancy of the light.

A chimney principally intended to carry off the products of combustion and the air which the flame sets in motion, is fixed to the top of the cupola. It is capped with a spherical bowl pierced in its lower

part with escape-holes In lanterns of the three first orders, the air required for combustion enters by the hollow column contrived for the descent of the lamp weight, by the partly opened door of the stair-case, and often by ducts opened in the masonry of the light-room, the orifices of which are governed by a register Longitudinal openings, which can be opened or closed at will, are also introduced in the sole-plates of the lanterns, above each of which at the base of the cupola, is a small ventilator, which helps to get rid of the hot air, and consequently to attract the current of cold air

A large copper bowl is suspended in each lantern above the apparatus to receive any possible water drip which might fall on the chimney or lamp.

The glazing is of glass 0 008 m in thickness The sheets are received in a rebate, and are fixed by metal mouldings screwed both to the standards and astragals. Care is taken to give them about 0 002 m play, in order to prevent fracture in the oscillation produced by storms. They are placed in thin strips of lead, and then thoroughly putteyed

Many glasses in lanterns have been broken, in spite of their thickness, by birds attracted by the glare of the light The lanterns of light-houses peculiarly exposed to damage of this kind are, in France, enveloped in a guard of brass-wire about 0 0012 m in diameter, with a mesh of 0 08 m. Some diminution results in the brilliancy of the light, but it has been noticed that the number of birds which impinge against the lantern decreases year by year, so that it is expected that these guards may be, at no distant date, dispensed with

All the lanterns are furnished with a lightning-rod, the conductor of copper wire, and the point of platinum.

Plate II exhibits the above arrangements A complete lantern of the first order, with glazing, &c , costs in France about £810

English Lantern —The usual English lantern is of an octagonal shape, and is for the first order, 13 feet in diameter, formed in plan of cast-iron panels, with the joints planed to the proper bevel, so as to fit solidly together

The standards supporting the dome, and forming the framing for the plate-glass panes, are inclined alternately right and left, which adds greatly to the stiffness of the structure, while the light is not entirely

intercepted in any vertical plane, as would be the case if the standards were vertical The standards are of wrought-iron of a bevel section, and to prevent corrosion by the action of sea air, are protected, as in France, along the outer edge, with a gun-metal facing, grooved to receive the plate-glass panes which are secured as in the French lanterns. Two sets of gun-metal astragals to support the glazing are fixed horizontally between the standards, at the level of the joints between the refracting lenses and upper and lower cata-dioptric prisms of the optical apparatus, so as not to stop any of the rays emanating from the light

The glazing arrangements are similar to the French, with glass ⅜th inch thick, and storm panes are provided in case of accidents by birds, &c The copper dome is made double with an air space between, and the cowl revolves with the weather-cock to turn the openings away from the wind

The cost of such a lantern is about £860

Scotch Lanterns —Mr Alan Stevenson's objection to the vertical direction of the astragals in lanterns on the French system, led him to give a diagonal direction to the joints, considering that this direction not only equalized the effect of the light, but gave greater stiffness and strength to the frame-work of the lantern and to the panes of glass, and thus rendering it safe to use more slender bars, while they absolutely intercepted less light This form of lantern, which is made entirely of gun-metal, is extremely light and elegant The dome is of copper, double, the inside lining being of sheet-iron, with an air space between The glazing arrangements are as above, and storm panes are similarly provided

The cost of such a lantern is, however, over £1,250 for a first order light

Douglas's Lantern —The frame-work of this very beautiful lantern is built helically and of steel It returns, however, to the objectionable conical form of roof, and the cost is greater than any of the others, being, for a first order light about £1,350 * It seems to have the form, however, which offers the greatest resistance to storms, and which will afford the greatest strength to the glazing, though it is not probably better in this respect than the Scotch lantern, which is of bell-metal with

* I should say, however, that the diameter of a 1st order lantern, according to the Trinity Board Regulation, is 14 feet instead of 13 feet

spherical cupola. There is less absolute obstruction of light also for revolving lights, but that these advantages compensate an extra cost of £500 over the French or English lanterns above described, I am hardly prepared to recommend the Indian Government to admit

In Scotch and English light-houses the lightning conductor is generally of solid copper $\frac{3}{4}$th inch diameter instead of copper wire

The ventilation of the English and Scotch lanterns appears scarcely to receive that attention which is given to it in France, but I think the double cupola of the former a very desirable arrangement for India, for the rest, I think, for fixed lights, the French system of vertical standards and horizontal astragals desirable, as these in both cases may then be made to coincide with the joints of the optical apparatus, and thus the double occultation will be saved For revolving lights, the Scotch or English systems may be the best, the English having £400 advantage in cost, but the French have failed to appreciate the advantages of the diagonal system so far at least as not adopting it is concerned, involving, as a change would, the alteration of machinery without probably, in their opinion, adequate result But certainly (the cost being the same, or nearly the same) for revolving lights, the inclined verticals would be desirable, and perhaps of all, Mr. Douglas's is theoretically the most perfect arrangement, however it may turn out in practice, and one has lately been put up at Lowestoft on the east coast of England, and six or seven others are about to be put up. I think I have given sufficient information in regard to them to enable every person to judge for himself how far the advantages secured by these diagonal lanterns counterbalance the extra cost.

A F

No. CLXXIII

THE NORMANDY CONDENSER

Report on the Normandy Condenser, lately erected in the Fort at Delhi, for the purpose of suppling pure drinking water to the troops in Garrison By Crawford Campbell, Esq, *Executive Engineer*.

The condenser purchased for Delhi by the Executive Engineer, Presidency Division, was a second-hand one, bought from some troop-ship by a firm at Howrah, fitted up with a new boiler, and put in working order by Hugh McLardy and Co, of the Vulcan Foundry

Of these condensers and their mode of working, a full account, written by Dr Normandy himself,* will be found in the third volume of Ure's Dictionary, Art *Sea water*, and there is also a brief description of them in the new volume (Appendix) to Tomlinson's "Cyclopœdia of Useful Arts," lately published, but as neither of these works may be readily available to those who peruse this report, it will be as well to give here a short description of the apparatus, illustrating it by a diagram of the essential parts of the machine, and omitting all those minor details which, however much they may contribute to the success of the condenser, do not affect any particular principle involved in it

Its distinguishing features, as compared with ordinary condensers, are—(1), That the water is aerated and cooled during the process of distillation, and is thus available at once for drinking purposes, (2), By the addition of a charcoal filter, the empyreumatic odor and flavor peculiar to

* The copy in my possession is the fifth (enlarged) edition, published in 1860 I do not know whether the prior editions contain Dr Normandy's description

distilled water are entirely removed, and (3), By a system of double condensation, to be explained hereafter, the fuel is made to do double duty, and very economical results are obtained For the second of these, Dr Normandy claims a large share of the merit due to his invention, but the use of charcoal for deodorising water is so well known, and has been for so long* before the public that we may dispense with any further notice of it here

Omitting, therefore, the filter, and also the boiler, the main portions of the apparatus may be described as four in number, viz, the evaporator, the condenser, the aerator and the refrigerator, whilst there are three sources of supply to be considered—(X), The primary steam from the boiler, (Y), The cold water used in refrigerating and condensing, and (Z), The secondary steam from the evaporator

Let us take X first, it is generated in the boiler under pressure and passes into the evaporator A † *as superheated steam* It is thus capable of condensation by the boiling water in A whilst passing through the congeries of pipes marked *bb*, whence it flows into the refrigerator as non-aerated water The cold water (Y) is first used in the refrigerator to cool the water in *f*

Slightly warmed by this process, it is next forced into the condenser (B), where it converts the secondary steam from A into water In doing so, its temperature rises to 200°, and it parts with all the air contained in it (*see* after) It then passes into the evaporator A, where it condenses the superheated steam in *b*, is raised thereby to a temperature of 212°, and thus becomes converted into the secondary steam Z. This steam passes by the pipe *d* into the series of pipes marked *e*, and along with it passes a large amount of air from the aerator D, which becomes amalgamated with it when it is condensed in E, so that it passes into the refrigerator C as *super*-aerated water In the pipes *f*, the non-aerated water from *b*, and the super-aerated water from *e*, mingle and are cooled, passing thence into the filter from which they emerge (it is asserted) in the shape of pure ordinary spring water

The manner in which the aerator acts is very simple and beautiful Water, as is well known, parts with the air contained in it at a temperature of 130° As, therefore, the cold water (Y) enters the condenser B

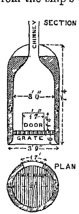
* Without referring to the "three gurha" filter, so common in India, it may be noticed that the first filter in which charcoal was used was patented in England so far back as 1814

† At Delhi the pressure is 20 lbs., and temperature is 259°.

at about 90°, and quits it at a temperature about 200°, it follows that in this vessel all the air contained in it is drawn off. This air is forced through the pipe D into the steam chamber *cc* by the simple expedient of keeping the condenser B always full of water, when once it has reached the chamber *cc*, its mixture with the secondary steam and its subsequent amalgamation with the water produced therefrom will be readily understood.

This aerator acts in another way, which does not seem to have been suspected by Dr. Normandy. The air passed through it has so high a temperature, that it assists materially in boiling the water in the evaporator. By some oversight we forgot to fix this pipe when setting up the machine, and worked without it for several days. When the omission was detected and made good we found a very large increase in the quantity of distilled water produced.

As regards the boiler, Dr. Normandy contemplated using the steam from the ship's own boilers in the case of a steamer, or from a small apparatus put up in the caboose of a sailing ship. The one made up for Delhi was manufactured expressly by Mr. McLairdy, and its plan and section are shown in the margin. It is a modification of the Cornish system, *i. e.*, the fire is surrounded by water, but it is placed *vertically*, and there are no flues, the heated air passing off at once into the chimney, all benefit from it being lost. The boiler is besides much too large for the apparatus to which it is attached, and the result has been a very great waste of fuel, and a very serious enhancement of the cost of working.



There were also some minor defects in the boiler, but these I had remedied before it left Calcutta.

On the arrival of the apparatus at Delhi, I proceeded to set it up in one of the rooms attached to the large Baolie inside the palace, about 15 feet above the level of the water therein.

This was done upon the strength of a verbal assurance from the sellers that the pump could easily lift that distance, but, when fixed and at work, it proved itself quite incapable of doing so. As it was then too late to change its position, I was forced to use canal water in our experiments, which is already the best in Delhi, although, of course, it is not wholly free from impurities. This proved rather an advantage, however, as owing to the

absence of saline and other incrustations on the boiler, there was less waste of fuel than would otherwise have been the case.

I also found that Dr Normandy's filter was not large enough to purify the water sufficiently, and an additional one, on a simple plan, was therefore made up. In the original, the water passes along a distance of 4·12 lineal feet, the charcoal having an area of 125 square inches, whilst in the additional one it passes over 22·50 lineal feet having an area of 70 square inches of charcoal. Even after passing through this latter filter, the water had a strong chalybeate flavor, or, to describe it more correctly, a strong smack of the iron vessel in which it had been generated. It was, however, always bright and sparkling, and had none of the empyreumatic taste or odor found in ordinary distilled water.

The experiment commenced on the 1st of January, and was continued throughout the month. The out-turn varied from 250 to 300 gallons per diem. The fuel used was principally the boughs and refuse pieces of trees purchased for scaffolding at the new barracks, and much of it was green and of but little value as fuel. It had, however, the merit of cheapness, and this was my reason for using it. The water as it came from the filters was stored in large casks, whence it was drawn off by the bheesties as required and conveyed *in their "massaks"* to the cook-rooms and barrack filters. At first they refused to use it at all, and orderlies had to be detailed to enforce their doing so.

The experiment may be considered as a successful one, but on this point I would refer to the careful and candid report of Major Maitland and Dr Beatty, of H. M.'s 79th Highlanders, who took an interest in the experiment and exerted every effort to contribute to its success. The report of the Officer Commanding the Royal Artillery is also forwarded: it is not so satisfactory as the others, but I cannot help thinking that the comparative failure there, was due to want of proper precautions and to prejudice on the part of the men. It is to be regretted that the course pursued in the Commissariat Department, when testing malt liquor for issue to the canteens, was not followed in the present instance. The report of a Sub-Committee of intelligent Non-Commissioned Officers would have afforded the best criterion of the soldiers opinions in the matter, which are what we want most to get at.

Personally I am of opinion that the water was not so pleasant as that

river water hitherto supplied to the troops. I also think that it should never have passed through the bheesties "massaks." The impurity of these bags, used year after year without being cleaned out, is well known; and in any future experiments I would recommend the employment of tin pails slung in banghy, (similar to those used by milkmen at home,) for the conveyance of the water from the condenser to the barracks.

I now come to the question of cost, for many reasons the general experiment afforded no safe data, and I accordingly undertook a series of separate experiments in each sort of fuel procurable at Delhi. The results are embodied in the tabular statement annexed, marked A. The fuels used in these experiments were the best of their respective kinds. The *oopla* well dried, the wood well seasoned and in small billets, the charcoal of babool wood, and the coal "Raneegunge large, steam." The results are interesting, and are of considerable value in determining the weak parts of the machine, and the points on which it requires improvement. Thus, from the result given in column 21, it would appear as though *oopla* and wood have a high comparative value as economical fuels, but a closer examination shows that this is a fallacy, and that they owe their apparent superiority to the defects inherent in the boiler. It is so large that heat concentrated in a small space, like that given out by coal and charcoal, does not act so quickly upon the water as a large mass of light burning fuel which fills up the fire-box. Thus, for every 100 lbs of fuel expended in one hour upon keeping the water at boiling heat, it takes 141 lbs of oopla, 167 lbs of wood, 243 lbs of charcoal, and 300 lbs of coal, per hour, to raise the water to that heat. It is this enormous wastage which makes the use of the superior fuels so expensive, weighing down their economy in actual working. How great this is may be gathered from column 15, where it will be seen that, despite the great wastage which of course attends this part of the operations also, one pound of coal did six times as much duty as one pound of oopla, the former distilling 4.351 gallons against 0.700 gallons distilled by the latter. I estimate the wastage of coal in the present boiler at from 50 to 66 per cent of the whole amount burnt, whereas, it appears to me, that the boiler is peculiarly well adapted for oopla, and that the figures given for this fuel in column 17-21 represent its *ultimate* working strength. If so, it follows that the Delhi condenser, worked with oopla, can turn out no more than 875 gallons per diem,*

* i. e., a working day of about 12 hours, being 2 hours for getting up steam, &c., and 10 hours actual working.

whilst with coal, burnt in a proper boiler, it could turn out between 2,500 and 3,000 gallons, so that it would require about 3 machines worked with the cheaper fuel to equal the out-turn of one worked with coal. It follows therefore that, even at the present high price of coal, it will be cheaper to work the condenser with that article, burnt in a proper boiler, than with oopla or wood burnt in the present one.

Another important point upon which this table of experiments throws light, is the duty performed by the superheated steam. In an ordinary boiler, 1 lb of coal evaporates 9 lbs ($\frac{9}{10}$ths of a gallon) of water. For his apparatus, Dr Normandy claims an evaporating power of 12 or 14 lbs, but states, that by increasing "the *number* of evaporators" it would work up to 30 or 40 lbs. This is quite a fallacy, for the table shows clearly enough that *the power of the machine increases in proportion as the temperature of the primary steam is raised*. Thus, in our experiments with a pressure of 20 lbs. per square inch (equal to a temperature of 250°), 1 lb of coal evaporated from 38 to 49 lbs. of water, and there is no doubt that, with a more suitable boiler, we could easily evaporate from 103 to 150 lbs with steam of the same temperature.

The question next arises whether the experiment has been carried far enough with the imperfect machine at our disposal. It will be seen that Major Maitland thinks we should continue it for another three months; but I do not see that any good would result from this, because the use of condenser water for so limited a period, by a portion only of the men, can have no marked or trustworthy result so far as the Delhi sore is concerned. It must be remembered, that only the men in the two companies inside the Fort are able to use it, and these men only partially; when on duty at the Cashmere barracks, on sentry at the quarter-guard, or in hospital, they must drink well water. Even were the condenser removed to the Cashmere gate, the same objection would still exist: whatever is done the men cannot always and at all times confine themselves to the water produced by it. And this objection applies with equal force to the argument, that by further use the men might come to like the flavor better. So long as they only get it at intervals the contrast with well water will be kept prominently before them; and at the end of the three months those who now dislike it utterly, and those who without liking it, think it to be good for them, will be of the same opinion as at the beginning.

These objections would not apply to a proposal for setting up a more complete apparatus and using nothing but condensed water throughout

the garrison But, were this done, it would be necessary to distil a sufficient quantity, not merely for drinking but for ablutionary purposes as well, for, if the Delhi sore be propagated by impure water, it is most probable that it is so propagated by external contact Before such an experiment can be carried out, it will be necessary to make up a new boiler for the present condenser, and to purchase one or two more, or, better still, to have a new and more powerful machine made to suit the special requirements of the case In the Appendix, marked C, will be found a rough scheme for such a machine, and in it I have suggested the use of a reservoir for still further aerating that portion of the water which is to be used for drinking purposes My object in this is to try and get rid of the peculiar flavor referred to in page 29, which makes the condensed water so unpalatable to the soldiers, and which must always prove a bar to its success That it cannot be got rid of by any amount of filtering is, I think, proved by our experiments, for I added 300 per cent to the power employed by Dr Normandy, and after this the water was passed through the barrack stands, but without any effect I believe it to be due to the inefficiency of the artificial aeration which takes place in the machine. In nature this process is a slow and gradual one, and distilled water requires long exposure to the atmosphere and some amount of agitation, before it becomes saturated with its due proportion of air

The only drawback to the scheme, as sketched, will be its very great cost, both in the first instance and in the annual expense Are we justified in incurring this when we have the water of the Western Jumna Canal always on hand in the palace, water which is remarkably good and wholesome, and which by a simple arrangement of filters can be freed from all organic impurities, and made available at a small cost for the use of the garrison? To this source we should, I think, look for our supply of water, not only inside the palace, but throughout the city and civil lines If the object of giving the men pure water is to eradicate thereby the Delhi sore, it will not be sufficient to apply our remedies to the supply of the palace only. The Delhi sore is a contagious disease, and must be extirpated in the city before the garrison can be wholly freed from it. And the soldier must have pure water to drink, not only in his lines and barracks, but also when he goes abroad for recreation or on business.

C. C.

APPENDIX A.—Table of experiments upon the capabilities of the Delhi Condenser

General. A				Getting up steam. B			CONDENSING WATER — Actual data obtained. C				CONDENSING WATER — Calculated data for 10 hours working D					Final results, being the data under B and D combined E				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Nature of fuel	No of experiment	Contents of boiler	Pressure on safety valve	Time occupied in getting up steam	Quantity of fuel expended	Cost of fuel expended	Time during which worked	Quantity of fuel expended	Cost of fuel expended.	Total distilled water produced	Quantity of fuel expended	Cost of fuel expended	Total distilled water produced	Amount of distilled water produced to every lb of fuel	Cost of fuel required to produce one gallon of distilled water	Total amount of fuel expended throughout whole experiment	Cost of fuel for whole experiment	Distilled water produced	Amount of distilled water produced to each lb of fuel throughout	Cost of fuel required to produce one gallon of distilled water
		gals	lbs.	hrs	lbs.	as	hrs.	lbs.	as.	gals.	lbs.	as.	gals	gals.	as.	lbs.	as.	gals.	gals	as
Oopla, ..	1	170	20	1¼	250	5 00	6	750	15 00	550	1250	25 00	917	0 733	0 027	1500	30 00	917	0 611	0 033
	2	170	20	1½	220	4 40	6	720	14 40	500	1200	24 00	833	0 666	0 029	1420	28 40	833	0 587	0 034
	Mean	170	20	1⅗	235	4 70	6	735	14 70	525	1225	24 50	875	0 700	0 028	1460	29 20	875	0 599	0 033
Wood,	3	170	20	2	246	24 60	6	451	45 10	600	752	75 17	1000	1 329	0 075	998	120 27	1000	1 002	0 120
	4	170	20	1¾	246	24 60	6	451	45 10	600	752	75 17	1000	1 329	0 075	998	120 27	1000	1 002	0 120
	Mean	170	20	1⅞	246	24 60	6	451	45 10	600	752	75 17	1000	1 329	0 075	998	120 27	1000	1 002	0 120
Charcoal,	5	170	20	1½	123	30 75	6	246	61 50	600	410	102 50	1000	2 439	0 102	533	164 00	1000	1 876	0 164
	6	170	20	1	102	25 75	6	205	51 25	600	342	85 42	1000	2 924	0 085	444	136 67	1000	2 252	0 136
	Mean	170	20	1¼	112	28 25	6	225	56 37	600	376	93 96	1000	2 681	0 093	488	150 33	1000	2 064	0 150
Coal, ...	7	170	20	1¼	102	40 20	5	144	57 60	550	288	115 20	1100	3 819	0 105	390	172 80	1100	2 820	0 157
	8	170	20	1¼	101	40 10	8	205	80 20	1000	256	102 50	1250	4 883	0 082	357	182 70	1250	3 501	0 146
	Mean	170	20	1¼	101	40 15	6½	174	68 90	775	272	108 85	1175	4 351	0 093	373	177 75	1175	3 160	0 151

APPENDIX B.—Table showing the cost of working the Normandy Condenser at Delhi with the existing boiler.

Items of expenditure	Oopla	Wood	Charcoal	Coal	Remarks
	Rupees	Rupees	Rupees	Rupees	
Wages of engineman,	0 666	0 666	0 666	0 666	Cost per diem
" of stoker, cooly and chokeydar,	0 500	0 500	0 500	0 500	
Petty repairs,	0 250	0 250	0 250	0 250	
Fuel,	1 531	7 517	9 395	11 109	
	2 947	8 933	10 811	12 525	
Contingencies 5 per cent,	0 147	0 456	0 540	0 626	
Daily cost, rupees,	3 094	9 379	11 351	13 151	
	Gallons	Gallons	Gallons	Gallons	
Daily production,	875	1,000	1,000	1,175	
Annual cost, rupees,	1,129	3,423	4,143	4,800	
	Gallons	Gallons	Gallons	Gallons.	
Yearly production,	3,19,375	3,65,000	3,65,000	4,28,875	

APPENDIX C.—*Rough specification for a Normandy's Condenser for the Fort at Delhi, capable of supplying the whole of the garrison and other residents therein with water for drinking and ablutionary purposes.*

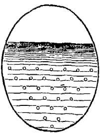
The machine to be capable of turning out 6,000 gallons per diem, or* 10 gallons per head for the whole of the residents inside the palace, including men, women and children.

To produce this the boiler should be capable of evaporating 600 gallons of water per hour. The fuel used will be coal.

The boiler to be on the Cornish system, 15 feet long 4½ feet diameter, with an interval flue 2½ feet diameter, containing the fire grate at one end. There will be one bottom and two side flues, each presenting a surface of 2½ feet to the boiler; these flues will be on the "bridle draught" plan. The fire grate to be 3 feet deep by 2½ feet wide, and to be fur-

* *i. e.*, Drinking and cooking, .. 3½
Washing and bathing, .. 6½
—
10

nished with a dead plate, so as gradually to heat the coals before they are put on the fire, and thus economise fuel There will be $7\frac{1}{2}$ square feet of fire grate surface and 230 square feet of heating surface The boiler to be worked with a pressure of $1\frac{1}{2}$ atmospheres, or $22\frac{1}{2}$ lbs per square inch The exact dimensions of the condenser and evaporator may be left to the manufacturer's judgment, but the latter should be large and roomy, and should be placed horizontally It should be of the section shown in margin, the pipes running through the whole length of the evaporator



The object of this is to get greater water space, more heating surface, and a large steam chamber There should be two condensers, and the secondary steam should be conveyed into them as quickly as possible It need not at Delhi pass through a priming box, as the water used for condensing is so little impregnated with salts as not to require this precaution. It will be quite sufficient if all connection pipes are made of a somewhat large diameter.

The engine connected with the apparatus must be capable of pumping up 70 gallons per minute from a depth of 40 feet If more convenient, this engine may be erected separately with a boiler of its own, and the one previously specified may then be reduced somewhat in dimensions The water should be pumped up into a tank with supply pipes to the boiler and refrigerator, and not (as now) direct into those vessels.

There will be no filter attached to the machine, but the water will pass at once into the supply tank The tanks are shown on *Plate* VI, they must be in a covered shed having all openings closed with wire gauze

The water will be received into the supply tank, whence it will pass through the filter into the filter chamber The filter will be of flagstones filled in with charcoal in the usual manner From the chamber the water for drinking purposes will pass into the reservoir by means of 6 copper pipes, having jets at intervals of every 4 feet These jets will be of the convolvulus pattern so as to throw the water well about in small drops, and aerate it as thoroughly as possible The overflow from the supply tank and reservoir will pass into the service tank, whence it will be drawn off for all ablutionary purposes for which 3,900 gallons will be

required daily, the service and supply tanks holding about 10,000 gallons The reservoir holds 14,000 gallons, or about 7 days supply for drinking and cooking purposes, which will therefore be thoroughly well aerated and sweetened before being used by the troops

The area of filter will be so arranged that only a portion of the supply will pass through it, the remainder passing direct into the service tank by the overflow, marked *a a*.

No CLXXIV.

NOTES ON RETAINING WALLS.

(3RD PAPER.)

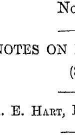
BY J. H. E. HART, ESQ., *Executive Engineer, Dharwar.*

IF, instead of giving a fractional increase to the breadth of the base of Retaining Walls, as recommended in the previous article, No XLVI, Vol I, page 450, we adopt the more elegant principle mentioned in Professor Rankine's works, which is, that "the line of resistance must not deviate from the centre of figure of any joint by more than a certain fraction (q) of the diameter of the joint, measured in the direction of the deviation," certain alterations must be made in the equations for finding the breadth of walls.

In the equations hitherto obtained, the line of resistance—line of resultant pressures—has been assumed to pass through the outer angle of the base of the walls, which would make the fraction $q = \frac{1}{2}$, and the walls would be in a position of bare stability, being in exact equilibrium with the overturning pressures. Rankine says, however, that an examination of practical examples determines values for the fractional deviation of the line of resistance, from the centre of the base, which give $qb_1 = \frac{3}{8} b_1$ to $\frac{1}{4} b_1$.

Fig. 18

Fig 19.



These principles are examplified in *Figs* 18 and 19. In the former figure, (R) the resultant of the moments of the pressure (P) and of the weight of wall (V) passes through the extreme edge of the base of the wall, while in *Fig* 19 its deviation from the centre of the base c is limited to the distances CD $= qb_1$. In obtaining equations

for the breadths of walls, in which the deviation is thus limited, we must equate the moments of stabilities and pressures round the extreme limit of deviation at D

The equation for the stability of a standard wall will be

$$W_1 h\, q b_1^2 = \frac{Ph}{3} \;\therefore\; b_1 = \sqrt{\frac{P}{W_1 3 q}}. \qquad \qquad (17)$$

Tables have already been calculated for the breadth (b) of standard walls* in which $q = \frac{1}{2}$, wherefore the breadth (b_1) of standard walls in which q has other values is thus expressed —

$$b_1^2 \quad b^2 \quad \frac{1}{2} \quad q \quad \therefore b_1 = b\sqrt{\frac{1}{2q}} \qquad \ldots\ \ldots\ldots(18)$$

Values for the $\sqrt{\frac{1}{2q}}$ are as follows —

$q =$	$\frac{1}{2}$,	$\frac{3}{8}$,	$\frac{1}{3}$,	$\frac{1}{4}$,
$\sqrt{\frac{1}{2q}} =$	1 00,	1 155,	1 225,	1 414,

therefore for standard wall, in which q has any value as above, we have only to multiply the breadth of the standard wall, obtained from the co-efficient (k) of the Tables, by the proper values of $\sqrt{\frac{1}{2q}}$ corresponding to q as given above

Thus —

To find breadth b_1 of a standard wall, when $q = \frac{1}{3}$

$$\text{When } W_1 = 150 \text{ lbs}, \; W = 62\,4 \;\frac{W}{W_1} = \frac{S}{S_1} = \frac{1}{2\,4}, \; \theta^\circ = 0$$

then $b_1 = {\cdot}373\, h$ by Table, and $b_1 = 373h \times 1\,1225 = 4569\, h$

The base breadth of a wall of any other section is obtained by equating, as before, its moment of stability about D with that of a standard wall, thus —

$$W_1 A\, y' = W_1 h\, q\, b_1^2 \; \ldots \quad \ldots \quad . \quad . \quad \ldots \; . \; . \; (19)$$

in which y' corresponds to y in equation (4), and is the leverage of the wall about the extreme limit of the deviation of the line of resistance, its value will be

$$y' = y - \frac{x_1}{2} + q x_1, \quad \ldots\ldots\ldots\ldots\ldots \;\; \ldots \quad . \; \ldots (20)$$

where x_1 is the breadth of base of the wall, y as before, being the horizontal distance of the vertical through the centre of gravity of the figure of the section of the wall, measured from the outer edge of the base. $y - \frac{x_1}{2}$ corresponds to q_1 in Rankine's equations

* *See* Vol I, pages 338 and 440

Solving equation (19), for the various sections of wall, we have the breadths of wall as in the following Table of equations

TABLE VI

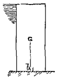
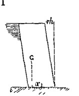
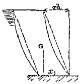
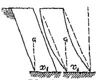
Description and section of wall.		General formula	Particular cases			
			$q = \frac{1}{2}$	$q = \frac{3}{8}$	$q = \frac{1}{3}$	$q = \frac{1}{4}$
Standard wall	20 	$b_1 = b\sqrt{\frac{1}{2q}}$	$b_1 = b$	$b_1 = 1\ 155\ b$	$b_1 = 1\ 225\ b$	$b_1 = 1\ 414\ b$
Reclining rhomboidal wall with straight batter.	21 	$x_1 = \sqrt{b_1^2 + \left(\frac{rh}{4q}\right)^2} - \frac{rh}{4q}$	$x_1 = \sqrt{b_1^2 + \left(\frac{rh}{2}\right)^2} - \frac{rh}{2}$	$x_1 = \sqrt{b_1^2 + \left(\frac{2}{3}rh\right)^2} - \frac{2}{3}rh$	$x_1 = \sqrt{b_1^2 + \left(\frac{3}{4}rh\right)^2} - \frac{3}{4}rh$	$x_1 = \sqrt{b_1^2 + (rh)^2} - rh$
Do do with curved batter	22 	$x_1 = \sqrt{b_1^2 + \left(\frac{rh}{3q}\right)^2} - \frac{rh}{3q}$	$x_1 = \sqrt{b_1^2 + \left(\frac{2rh}{3}\right)^2} - \frac{2rh}{3}$	$x_1 = \sqrt{b_1^2 + \left(\frac{rh}{8}\right)^2} - \frac{rh}{8}$	$x_1 = \sqrt{b_1^2 + \left(\frac{rh}{9}\right)^2} - \frac{rh}{9}$	$x_1 = \sqrt{b_1^2 + \left(\frac{rh}{12}\right)^2} - \frac{rh}{12}$
Maximum case of 21 and 32 vertical through centre gravity cuts, inner edge of base.	23 	$x_1 = b_1\sqrt{\frac{2q}{1+2q}}$	$x_1 = 707\ b_1$	$x_1 = 6547\ b_1$	$x_1 = 6327\ b_1$	$x_1 = 5774\ b_1$

TABLE VI.—*(Continued)*

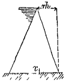
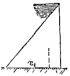
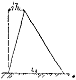
Description and section of wall		GENERAL FORMULA	PARTICULAR CASES			
			$q = \frac{1}{2}$	$q = \frac{3}{8}$	$q = \frac{1}{3}$	$q = \frac{1}{4}$
Triangular wall with a face batter $= rh$	24 	$x_1 = \sqrt{b_1^2 \frac{12q}{1-6q} + \left(\frac{2rh}{1-6q}\right)^2} - \frac{rh}{1-6q}$	$x_1 = \sqrt{3\,b_1^2 + \left(\frac{rh}{2}\right)^2} - \frac{rh}{2}$	$x_1 = \sqrt{3\;6\,b_1^2 + (8rh)^2} - 8rh$	$x_1 = \sqrt{4\,b_1^2 (+rh)^2} - rh$	$x_1 = \sqrt{6\,b_1^2 + (2rh)^2} - 2rh$
Ditto plumb faced $rh = 0$	25 	$x_1 = b_1 \sqrt{\frac{12q}{1-6q}}$	$x_1 = 1\;732\,b_1$	$x_1 = 1\;897\,b_1$	$x_1 = 2\,b_1$	$x_1 = 2\;449\,b_1$
Triangular wall with a back batter $= rh.$	26 	$x_1 = \sqrt{b_1^2 \frac{12q}{1+6q} + \left(\frac{r^1h}{1+6q}\right)^2} + \frac{r^1h}{1+6q}$	$x_1 = \sqrt{\frac{3}{2} b_1^2 + \left(\frac{r^1h}{4}\right)^2} + \frac{r^1h}{4}$	$x_1 = \sqrt{\frac{4\;5}{3\;25} b_1^2 + \left(\frac{r^1h}{3\;25}\right)^2} + \frac{r^1h}{3\;25}$	$x_1 = \sqrt{\frac{4}{3} b_1^2 + \left(\frac{r^1h}{3}\right)^2} + \frac{r^1h}{3}$	$x_1 = \sqrt{1\;2\,b_1^2 + \left(\frac{2}{5} r^1h\right)^2} + \frac{2}{5} r^1h$

TABLE VI—*(Continued)*

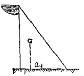
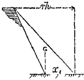
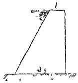
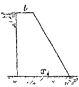
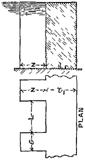
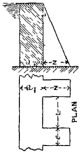
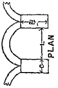
Description and section of wall		General Formula	Particular Cases			
			$q = \frac{1}{2}$	$q = \frac{3}{8}$	$q = \frac{1}{3}$	$q = \frac{1}{4}$
Triangular wall with plumb backed $r^1h = 0$	27 	$x_1 = b_1\sqrt{\frac{12\,q}{1+6\,q}}$	$x_1 = 1\ 23\ b_1$	$x_1 = 1\ 177\ b_1$	$x_1 = 1\ 155\ b_1$	$x_1 = 1\ 095\ b_1$
Maximum case of 24 vertical, through centre gravity cuts, inner edge of base $rh = 2\,x_1$.	28 	$x_1 = b_1\sqrt{\frac{4\,q}{1+2\,q}}$	$x_1 = b_1$	$x_1 = \ 925\ b_1$	$x_1 = \ 8954\ b_1$	$x_1 = \ 8166\ b_1$
Trapezoidal wall, plumb faced	29 	$x_1 = \sqrt{b_1^2\frac{12\,q-2t^2}{1-6\,q} + \left(\frac{t}{2}\right)^2} - \frac{t}{2}$	$x_1 = \sqrt{3b_1^2 - \frac{3}{4}t^2} - \frac{t}{2}$	$x_1 = \sqrt{3\ 6\ b_1^2 - 1\ 35\ t^2} - \frac{t}{2}$	$x_1 = \sqrt{4\ b_1^2 - 1\ 75\ t^2} - \frac{t}{2}$	$x_1 = \sqrt{6b_1^2 - 3\ 75\ t^2} - \frac{t}{2}$
Ditto plumb backed.	30 	$x_1 = \sqrt{b_1^2\frac{12\,q+2t^2}{1+6\,q} + \left(\frac{t}{2}\right)^2} - \frac{t}{2}$	$x_1 = \sqrt{\frac{3}{2}b_1^2 + \frac{3}{4}t^2} - \frac{t}{2}$	$x_1 = \sqrt{\frac{4\ 5}{3\ 25}\,b_1^2 + \frac{11\ 25}{13}\,t^2} - \frac{t}{2}$	$x_1 = \sqrt{\frac{4}{3}b_1^2 + \frac{11}{12}t^2} - \frac{t}{2}$	$x_1 = \sqrt{1\ 2\ b_1^2 + 1\ 05\ t^2} - \frac{t}{2}$

TABLE VI —(*Continued*)

Description and section of wall.		GENERAL FORMULA	PARTICULAR CASES			
			$q = \frac{1}{2}$	$q = \frac{3}{8}$	$q = \frac{1}{3}$	$q = \frac{1}{4}$
Vertical rectangular wall with rectangular counterforts.	31 	$x_1 = \sqrt{b^2 - \frac{CZ^2}{L+C} + \left(\frac{CZ}{L+C}\right)^2} - \frac{CZ}{L+C}$	Same as in general case			
Ditto with triangular buttresses	32 	$x_1 = \sqrt{2qb_1^2\frac{(1+6q)}{6(L+C)}CZ^2 + \left(\frac{(1+2q)Z}{2}\right)^2} - \left(\frac{1+2q}{2}\right)Z$	&c			
Rectangular buttresses arched with thin ring between	33 	$x_1 = b_1\sqrt{1 + \frac{L}{C}}$	Same as in general case			

In the case of walls of a vertical rectangular section, Rankine points out, that a triangular portion at the outer face of the wall may be removed without in any way influencing the stability of the wall, inasmuch as so long as the vertical through the centre of gravity of the part taken away does not fall behind the limiting position of the resultant (R), cutting the base, its removal cannot affect the position of the centre of resistance at D If, therefore, in *Fig* 19, we remove a triangle abB whose centre of gravity (g') is vertically over D, we have a trapezoidal wall with a battering face of unaltered stability, whose breadth at base is $= b_1$

In the triangle abB the distance of the centre of gravity from the face bB is $\frac{1}{3}ab$, and by construction is equal $\overline{DB} = \frac{b}{2} - qb_1$, therefore the line ab is equal $3(\frac{1}{2} - q)\ b_1$, and the top breadth (t) of the wall will be

$$b_1 - 3\,(\tfrac{1}{2}q)\ b_1 \quad \ldots \qquad \ldots \qquad (21)$$

the rate of batter of the wall being $3\left(\frac{\frac{1}{2}-q}{h}\right) b,$

$$\text{whence for } q = \tfrac{1}{2},\ \tfrac{3}{8},\ \tfrac{1}{3},\ \tfrac{1}{4},$$

$$t = b,\ \tfrac{5}{8}b_1,\ \tfrac{1}{2}b_1,\ \tfrac{1}{4}b_1$$

Walls sectioned thus are exceedingly useful as river dams or walls of reservoirs, where often a considerable breadth at top is expedient

In dams to resist water pressures, because of the certainty with which the laws which govern fluid pressures are known, we pass almost out of the region of speculation on the subject of the exact thickness of wall required Our only variable being the weight of the masonry, which is easily ascertained, a Table of considerable practical use may be constructed from equation (17), which, for water pressure, becomes

$$b_1 = 3\,225h\sqrt{\frac{1}{W_1\,q}} = h\sqrt{\frac{S}{S_1}\,6\,q} = \cdot 4083\ h\sqrt{\frac{1}{S_1\,q}} \quad \ldots \ldots \quad (22)$$

When W_1 is the weight of a cubic foot of the wall, S_1 its specific gravity, q the fractional deviation of the line of resistance As before, $b_1 = kh$

Table VII —Co-efficients of h to obtained thicknesses of standard walls to resist water pressure.

			Weight of cubic feet of wall						
$W_1 =$	100	110	120	130	140	150	160	170	180
			Specific gravity of wall						
$S_1 =$	1 6	1 76	1 92	2 08	2 24	2 4	2 6	2 73	2 9
			Co efficients of $h = k$						
Value of q $\frac{1}{2}$	456	435	417	400	386	373	358	350	339
$\frac{3}{8}$	527	502	481	461	445	430	413	400	391
$\frac{1}{3}$	560	534	511	490	473	457	439	429	415
$\frac{1}{4}$	646	616	590	566	546	527	506	495	479

The co-efficients are used in the same way as those in Tables, pages 338 and 449, Vol I For a mean of any of the above specific gravities or weights, the co-efficient will be a mean also, *e g*, for

$$W_1 = \frac{140 + 150}{2} = 145\,,\ K = \frac{386 + 373}{2} = 379$$

Example —Thickness of a reservoir wall 123 feet high, when the line of pressures is not to deviate further from the centre of the base than $\frac{1}{4}$ its breadth The weight of masonry, 150 lbs per cubic foot then from above tables, for $q = \frac{1}{4}$, $W_1 = 150$,

$$b_1 = kh = \cdot 527h = 64\ 8 \text{ feet},$$

and by values of t, from equation (21),

$$t = \frac{b_1}{4} = \frac{64\ 8}{4} = 16\ 2 \text{ feet.}$$

These dimensions are not very different from those taken by Colonel Fife, in his design for a dam at Kurrukwasla, in the Poona and Kirkee water supply project, an interesting discussion on which is published by the Bombay Government, in No II, Vol II, of Irrigation Series His dimensions are $b_1 = 66$, and $t = 16\ 5$, the difference probably arising from the slight back batter given to his wall, also it is possible he may have taken into account the effect of the force due to the velocity of the river, which (*vide* equation 14) would be obtained approximately from equation

$$W h b_1^2 q = 31\ 2 \frac{h^3}{3} + 976\ V^2 \frac{h^2}{2},$$

whence

$$b = \sqrt{\frac{10\ 4\ h^2 + 488\ V^2 h}{W_1 q}} \qquad \ldots \quad (23)$$

And if $V = 5$ feet per second, $b_1 = \sqrt{\frac{157342 + 1501}{37\ 5}} = 65\ 07$

The following sheet of examples, *Plate* V *Figs* 1 to 20, illustrates what has been written, and at the same time shows how the breadths of walls vary with q The walls are calculated to resist water pressures, and the weight of masonry, 140 lbs per cubic foot, represents fairly an average case

The upper row of sections is for walls of bare stability, according to the equations given in former articles, or in the table of equations at page 47, when $q = \frac{1}{2}$

The dimensions of base in *Fig* 1 is got thus —

$$b_1 = kh = 386 \times 40 = 15\ 44, \text{ for the standard wall},$$

of the other figures, from table of equations *e g*, *Fig* 2

$$x_1 = 707 b_1 = 707 \times 15\ 44 = 10\ 916$$

In the same manner the second, third, and fourth rows of sections are obtained, *e g*, *Fig* 6,

$$b_1 = kh = 445h = 17\ 8 \text{ for the standard wall, when } q = \tfrac{3}{8},$$

and for *Fig* 8,

$$x_1 = 1\ 897 b = 33\ 77$$

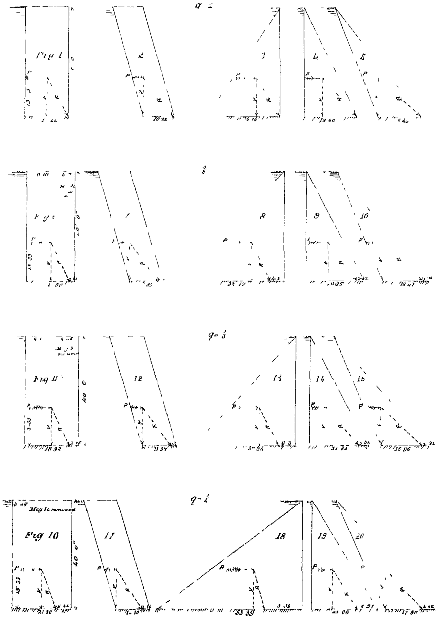
There is another consideration which should influence the dimensions of walls, it is that they should not slip forward on their bases from the horizontal pressure, it is easily shown that this will not occur so long as the resultant (R) makes an angle with the horizon greater than the angle of repose, which for green masonry is considered to be $36\frac{1}{2}°$ It is seldom necessary to investigate whether this condition is fulfilled or not; for even in walls of the smallest sectional area *Fig.* 5 in *Plate* V., the resultant makes an angle of over 40° with the horizon, and the angle increases with the decreasing values of q Further, the cohesion of the mortar is a very considerable element in this, as it is called, frictional stability of a wall, and it is neglected in the investigations connected with friction

J. H. E H

DIAGRAMS OF RETAINING WALLS OF EQUAL STABILITY,

when $q = \frac{1}{2}, \frac{3}{8}, \frac{1}{3}$ or $\frac{1}{4}$, respectively

FOR WATER PRESSURES



No. CLXXV.

KURRACHEE HARBOUR WORKS.

Review of the operations undertaken for the improvement of the Harbour of Kurrachee and of their effects. BY THE SECRETARY TO GOVERNMENT OF INDIA, P. W. D.*

THE question of improving the Harbour of Kurrachee was first raised in 1844, and in 1856 surveys were sent home and placed by the Court of Directors in the hands of Mr. Walker, the eminent Harbour Engineer. In consequence of his report, a Civil Engineer, Mr. Parkes, was sent out to visit the locality and collect data, and on his return, Mr. Walker again reported in 1858. No action followed until 1859-60, when the works recommended were partially sanctioned and commenced, and those sanctioned have since been carried on nearly to completion, with the exception of one work on which Mr. Walker laid great stress.

The harbour of Kurrachee is situated at a re-entering angle in the coast line, immediately adjoining the westernmost mouth of the Indus. To the west of Kurrachee, as far as Cape Monze, the general direction of the coast line is east and west. On the other side, its general direction is about south-east by south.

An inlet or estuary is formed at this re-entering angle by a narrow spit of sand running from the west and ending on the east in "Manora head," between, and within, which and the main land (Clifton) adjoining the Ghizree mouth of the Indus, is situated Keamari island. On the west of this island is the harbour of Kurrachee. On its east is the Chinna

* The foot notes are by the Acting Superintendent, Kurrachee Harbour Works.

creek. The town of Kurrachee is on the main land north of the island, and is connected with the latter by the Napier mole, finished in 1854.

At the head of the estuary and just to the west of the town of Kurrachee, is the mouth of the Lyari river, a torrent, dry, except during heavy rains, and then only running for a very few days in the year, perhaps ten.

When in flood, this torrent brings down sand, &c., but it seems by all who have considered the subject to have no appreciable effect upon the harbour, either in bringing down silt into it, or in contributing by scour to its deepening, or to the removal of the bar at its entrance.*

This bar or spit stretches across the entrance of the channel on the west of Keamari island, in an easterly direction, for nearly 1,000 yards from Manora head, where it commences, having a width there of about 300 yards.

On the top of the bar there was, previous to the commencement of the works, a depth of 8 feet at low water spring tides. There were two channels for vessels,—one "the western," with a depth of 11 feet across the bar; the other, "the eastern," round its eastern extremity, with a depth of 15 feet, its width being limited on the land side by the shelving of the coast.

Immediately south of Manora head and the bar, the line of soundings, 18 feet at low water spring tides is found, outside which the coast shelves gradually, but more rapidly, off and to the west of Manora than on the south-east in front of the delta.

The bar itself originally consisted throughout of very light sand to at least 20 feet in depth below low water.

The average range of tides over the bar is, springs $9\frac{1}{2}$ feet, neaps 3 feet.

The velocity of the ocean tide is from $\frac{3}{4}$ to 1 knot per hour.

The maximum velocity of the flood within the Keamari (west) channel was, previous to the commencement of the works, $1\frac{1}{2}$ knots, and of the ebb, $2\frac{1}{2}$ knots.

South of Keamari island will be observed a sandy spit. This used to be dry at lowest spring tides, but the flood and ebb passed over it with a velocity of $1\frac{1}{2}$ knots. Over the bar the flood was 1 knot, passing across

* The Lyari brings down during floods a large quantity of sand, &c., which has considerably increased the quantity of material to be removed in forming the new channel. Arrangements are about to be made to divert the waters of the branch which does harm from the new channel. They will thus be thrown into the harbour, where the current will be sufficiently strong to prevent any deposit taking place where it will interfere with navigation.

it obliquely in the direction (about north-east) of the Oyster islands, and gradually sweeping round to the north with an accelerated velocity, in no place greater than $1\frac{1}{2}$ knots

The tidal wave in fact approached Manora head from a direction west of south It also swept up the shore of the delta, and the two streams, as it were, uniting, poured into the estuary with a velocity about double that of the ocean tide

It was first asserted that sand was carried eastwards along the Manora spit, and swept round Manora head This has since been denied, but the Bombay Government in its Resolution of 16th May, 1865, says, "there is probably a movement of sand, though not perhaps to any great extent round the point, due to the south-east current which is known to exist"

South of Keamari island the sand travels to the westward, and the Keamari channel was, according to Mr Parkes' observation in 1858, being encroached upon thereby

It may be accepted that outside the bar the ocean current is from west to east Such was apparently the result of Mr Parkes' observations, and floating bodies, not carried to leeward, are looked for and found on Ghizree beach Colonel Tremenheere has erroneously had the credit of denying the existence of this littoral current, but he has contended that along the *delta* shore the current is from east to west, as far only as the harbour. Mr Parkes admits that the sand travels from east to west on the south of Keamari island, but *asserts* that along the Clifton beach the sand travels to the eastward This is pure assumption, for he adds,—"there are no materials to give positive evidence of this"

Colonel Tremenheere *asserts* the contrary

There are no facts whatever concerning the littoral currents beyond or south-east of the Chinna creek and Ghizree beach, and the fact that during the ebb of the tide, bodies floating out of the harbour are found on Ghizree beach, does not prove the non-existence of a littoral current towards the north-west as far as Keamari island Colonel Tremenheere, indeed, quotes the fact in favor of his assumed current towards the north-west along the Delta shore, but he adduces no *facts* in favor of its existence. Evidence is altogether wanting on this head *

* Since this review was prepared, information has been received that Colonel Tremenheere has made an experiment with floating bottles, which confirms his opinion, *see* his Report, dated Kurrachee, 4th August, 1865

Turning now to the harbour, it seems evident that its "very existence depends on the backwater"

The low water area from the bar to the south end of Napier mole, is 600 acres To the north end of Napier mole, including the above and the area of channels and creeks on the *west* of Napier mole, the approximate areas are—

At full tide,	6,000 acres
At half tide,	2,600 ,,
At low tide,	900 ,,

East of the Napier mole the area covered at high water is 1,800 acres, at half flood is 900, and the area of the Chinna creek always under water is 50 acres

The sectional area of the tidal channel at west end of Keamari was, according to Mr Walker's Report, at high tide 7,500 square yards, with a width of 1,200 yards, at low tide, 4,200 square yards To the south of this point the sections of the *channel* decreased in area, the water passing over the spit south of the island

Whilst at Kurrachee, in the cold season of 1857-58, Mr Parkes made observations on the tides He was not there *during the monsoon*, either then or during his subsequent visit, which Colonel Tremenheere considers most unfortunate, and fatal to his views and designs

Mr Parkes' "practical deductions" from the tidal observations were, that the tide, as it flows up the harbour, has a decided tendency to increase its range, and the removal of the bar and deepening of the channel to Keamari will encourage a still greater flow of tide

The results of Mr Parkes' observations (the value of which must be limited as they extended over a few months of the cold season only) were that the range of the tide was in 1858, 2 or 3 inches *greater* at Keamari than at Manora, and 10 to 15 minutes later. There was in 1863 still the same difference, an important point, as showing that the flow of the tide had not been sensibly choked by the narrowing of the entrance by the construction of the Keamari groyne (*see* below), nor has the full flow of the tide into the harbour been interfered with

In the shoal water outside Chinna creek, high water was 1 to 3 inches *lower*, and a few minutes later than at Manora. On the Chinna creek side of the Napier mole high water was 2 to 4 inches *lower*, and half an hour to an hour later (than at Manora?), while on the harbour side of

the Napier mole, $1\frac{1}{2}$ miles above Keamari, the high water rises 1 or 2 inches *above* the level at Manora, and the time is 20 to 30 minutes later. The "range" is not given at this point, as the bed is only 2 feet below half tide level

As far as they go, these observations seem to justify the deduction already stated

The ebb sets with considerable force over the bar and nearly at right angles to its length The direction of the *flood*, as already described, is more oblique across the bar

Mr Parkes also reported that the monsoon waves broke in 9 to 15 feet depth of low water, and that the height of the bar did not materially, indeed scarcely appreciably, alter by the action of the monsoon

Mr Parkes' theory as to the formation of the bar is, that the monsoon waves, in breaking, lift the sand and carry it on with them until their force is spent under the lee of Manora point The sand is then deposited, and forms the nucleus of the bar

As an important feature in the channel, the deep pool off "Deep-Water Point" should be noticed Mr Parkes' remarks concerning it are devoid of all point as to its formation

As to the capability of improvement of the harbour, Mr Walker wrote on the 8th September, 1856, as follows —

"It is satisfactory to me to be able to state, at the outset, that I think the objects * * * * in view, namely, the deepening or even entire removal of the bar, and the general improvement of the harbour of Kurrachee, are not of doubtful execution, but that, on the contrary, there is good reason to expect, through the application of proper means, the accomplishment of both, and this at a moderate expense, when compared with what I understand to be the almost national importance of a safe harbour at Kurrachee, capable of receiving and accommodating sea-going vessels of large tonnage"

28 Mr. Walker then recommended,—1st, The closing of the Chinna creek, and the addition of its estuary to the backwater area of the harbour, by opening passages in the Napier mole This involved a diversion channel and a bridge in the mole, 2nd, The construction of the Keamari groyne; 3rd, The construction of the Manora head groyne or breakwater These works to be carried out in the order in which they are here entered, and Mr Walker was—

"Strongly of opinion that the works combined with the general deepening and improving of the harbour by dredging, will remove the bar, deepen the entrance to not less than 20 feet at low water (if the bottom to this depth is of sand),* render the harbour of easy access, and tend to quiet it at and above the entrance

"Therefore, I think (Mr Walker adds), that they should be tried before going to any other more expensive work for the removal of the bar

"I do not, however, pledge myself to this, or that an east pier (in prolongation of the Keamari groyne) also may not be required.

"The most effective (work) for its cost (which would not be great), would be the bank or mole to prevent the loss of water south of Keamari," *i e*, the Keamari groyne

In his second Report, dated 28th October, 1858 (submitted after the harbour had been visited by Mr Parkes), Mr Walker states that his previous views are not only entirely confirmed, but the diversion, into the harbour, of the water which now passes in and out through Chinna creek, is of even greater importance than he had anticipated

The Manora breakwater was to be 1,500 feet long The Keamari groyne, 7,400 feet The eastern pier in extension of it, 2,600 feet, but to be postponed to the last, and carried out as found necessary †

"The result of every consideration I have given to the subject is that at least 20 feet at the low water of spring tides, 23 feet at the low water of neap tides, 25 feet at the high water of neap tides, and 29 feet at the high water of spring tides, with an ample width of entrance sheltered from the worst winds, may be depended upon "

Mr Walker's designs cannot be judged by the present results, for he did not specify the effect he anticipated from the several works, each by itself, and the Manora breakwater was, much to his regret, deferred, when the Home Government sanctioned the works The *principles* on which his designs were based were clearly—(1), The increase of the backwater basin. (2), The construction and rectification of the ebb and flow of the tide, and (3), The sheltering of the bar from the break of the waves Mr Walker is now dead

As respects the anticipated effect of the Keamari groyne *by itself*, a re-

* Which it was subsequently proved to be

† A length of only 1,500 feet is being now carried out, on Mr Parkes' proposals of 1864

ference to paragraphs 83-4-5 of Mr Parkes' first Report shows that,—Arguing on the result of a reduction in the quantity of backwater by the closing* of the passages by which some of the Chinna creek water used to pass through the harbour, and of a reduction in the channel by the natural raising of the sandbank south of Keamari by the sand which, as already mentioned, travels from east to west here, that result between 1854 and 1858 being an increase of depth,—*Mr Parkes* anticipated that the construction of this groyne would have "a still greater beneficial effect" This *may* have been intended to refer to the *channel* and not the *bar*, but it is not clear, Mr Parkes also expected "that nature will therefore make continued efforts to enlarge all the sections (of this channel), till they attain an uniform area."†

It may be better, before proceeding further, to describe the *objects* of these works as stated by the projector.

That of the Chinna creek has already been described.

The Keamari groyne, and its continuation, the eastern pier, were not only to confine the passage of the water, but to stop the movement of sand from the east

The Manora breakwater was to quiet the entrance by shutting off and breaking the south-west seas, so that they would not stir up sand at the entrance to be subsequently deposited on the bar or within the harbour

Three other works will be found alluded to in the earlier Reports, viz, the Napier mole bridge, the diversion channel for the Chinna creek, and

* By the construction of the Napier mole, which was finished in 1854

† A good general idea of the tendency of the works as yet carried out to equalize the upper sections of the harbour will be obtained by a comparison of the average of the first three, with that of 14, 15 and 16 sections, as shown by the different surveys

The average of 14, 15 and 16 sections was less than that of 1, 2 and 3—

In January,	1858,	by 21	per cent
,,	1863	25	,,
In October,	1863	20	,,
In January,	1864	17	,,
In March,	1864	11	,,
In May,	1864	16	,,
In October,	1864	16	,,
In January,	1865	15	,,
In May,	1865	11	,,

The sections of the October 1865 survey have not yet been plotted, but, taking the average depth of soundings, and multiplying by the length of sections, the decrease appears to amount to 14 per cent

The fair season appears from the above, each year, to have had the effect of increasing the equalization We may, therefore, look for a still greater improvement, even as compared with May 1865, in this respect, before next monsoon.

the Native jetty or quay. The first is finished. It was to provide a passage for the water to pass in and out of the Chinna Creek basin, the portion of the mole parallel to the bridge being removed. This removal was, in November 1864, to have been shortly carried out, but it was not cut through on 28th June, 1865.*

The object of the second requires no explanation. It was more than half finished at the end of 1864, but can be of no possible use until the mole is opened through.

The Native quay has nothing to do with the *improvement* of the harbour. It is merely a convenience of the port, and is nearly, if not quite finished.

Now, as to the extent to which the works designed to act on the bar have been carried out.

The Chinna creek closure has not yet been done. Mr. Parkes would now carry it out gradually and slowly; it "may be accomplished within a few years," so that the Keamari channel may gradually adapt itself to the additional quantity of water it will then have to carry. A consideration of the effects of the Keamari groyne, to be presently stated, will explain Mr. Parkes' caution. He is desirous to avoid that "temporary damage" to the channel, which may follow the immediate completion of the closure of this creek, and which did follow the construction of the Keamari groyne. "Thus," (Mr. Parkes writes, in his 2nd Report), "though the diversion of the Chinna creek water into the new channel will undoubtedly be a further great improvement for upper harbour navigation, the present state is so great an advance upon the past, that the second step is not urgent." The action on the bar of this extra backwater does not seem to be considered now, though in his Report, Mr. Parkes was of opinion that "the value of this considerable body of water will be great on the bar and entrance channels."

The Bombay Government, in the 6th paragraph of its letter, dated 30th March, 1865, write,—"The stopping of the Chinna creek would greatly

* Orders as to the cutting through of the Napier mole are daily expected.

The excavation on the west side of the mole has been already of very great use in rendering more easy the passage of boats to the Native jetty, where almost all shipments and landing of goods now take place. It has also, by facilitating the flow of tide, increased the scour over the bar, although as yet the Napier mole has not been cut through.

The Native jetty has been finished, and, with the exception of that part of the south wall which is to the east of Napier mole, and which cannot be made of use till the Napier mole shall have been cut through, has been thrown open to the public, and is of very great use.

increase the scour in the harbour channel, which it is not thought advisable to do until the channels have assumed their full sections, under the action that has now been brought upon them by the completion and extension of the Keamari groyne"

The Keamari groyne was completed in March, 1863, "and terminated at a most critical place, just opposite deep-water point." The groyne was carried out precisely to the distance projected, and it was never before indicated that the position of its extremity was "critical"

"The principal result is one for which, I (Mr. Parkes) confess, I was not prepared"

Before stating this result, it is first desirable to note the changes in the Keamari channel up to January, 1863, when the groyne was completed to the end of the Keamari spit

The upper part of the channel had been much increased in section, and it was calculated that about 25 millions of cubic feet of material had been scoured out. On the completion of the groyne Mr Parkes expected this result to be exaggerated.

By the survey of March, 1864, however, it appears that a contrary effect had resulted About 15 millions cubic feet had been washed back, and the channel differed little from what it was in 1858

This effect Mr Parkes considered anomalous and "merely incidental and probably temporary," "to disappear as the principles of the design are more fully carried out"

As to the lower part of the Channel from the groyne to the bar, the effect had been an increase of section up to March, 1864, the date of the last survey of which we have particulars.

Before describing the state of the bar, it may be noted that so far from the sections in the upper part of the channel attaining an uniform area, the difference between the upper and lower section of this part was almost identically the same in March 1864 as in 1858, the lower section being upwards of 6,000 square feet less than the upper *

* From the Tables, which have been prepared with great care from the original charts, it appears that in 1858, the difference between Nos. 1 and 16 sections was 7,584 superficial feet In March, 1864, 2771, or rather more than one-third of the difference in 1857 58

I assume, that in page 55, No 16 section is the one alluded to My remark (p 55) will show that in March 1864, the tendency to equalize the upper sections was very marked

No 1,	34,320	No 1,	34,685
No 16,	26,736	No 16,	31,914
	7,584		2,771

Now as to the changes in the state of the *bar*

From the plans attached to Mr Parkes' 2nd Report, it appears that just after the completion of the groyne, April 1863, the top of the bar had been scoured away from 8 to 11 feet, the *west* channel (over the bar) had increased from 11 to 12 feet in depth, and the *east* channel had shallowed from 15 to 14 feet *

After the monsoon, in October 1863, the plan shows that the bar is more continuous and almost as high as in 1858, its top being 9 feet instead of 8 feet The *west* channel is 11 feet again and narrower The *east* channel had opened out to its original depth.

In January 1864, the bar had increased both in length and width compared with 1858, the top is in $8\frac{1}{4}$, $7\frac{3}{4}$, and $7\frac{1}{2}$ feet, the *west* channel has a depth of $9\frac{1}{4}$ feet against 11 feet in 1858, and the east channel an available depth of 14 feet There are soundings of 15 and $15\frac{3}{4}$ feet, but the channel of 14 feet is only 170 feet wide, and "a ship could never with certainty pass over the exact spot on which the additional depth is found"

An inspection of the Table given in Colonel Tremenheere's Report shows that the sections which cut the bar had *increased* in area between January and April 1864, though in the latter month they were still much less than in October 1863

* The object of the designer was not to maintain the east channel, and, although it is most fortunate that that channel is in so good a state for navigation, the chief thing to ascertain is, whether the object intended has been to any extent carried out *That object was to scour a channel through the bar* In the line which I think it probable that Mr Walker had in view when he designed the works for the improvement of the harbour, the width at 14 feet below datum is now 400 feet, and at 11 feet 160, whereas in 1857 58 the widths at these depths were on the same line 530 feet and 300 feet, respectively

The tracings of the last chart which I have this day forwarded, will, I think, show that the obstacle to be overcome is now much less than it was before the works were begun

The east channel is now in a very favourable state for navigation Deep ships sail in and out constantly Compared with its state in May last, the bar is—

At 14 feet	level below	datum	270	feet	longer
,, 11 feet	,,	,,	550	,,	shorter
,, 8 feet	,,	,,	60	,,	ditto

A patch at 8 feet below datum at a distance of 2,900 feet from the fort and in the middle of the bar has been washed away

The north face of the bar at the end is about 200 feet more to seaward

The north side of the channel has receded about 200 feet, making the entrance much more direct

The bar, both at 14 feet and 11 feet, is narrower than in May last

The eastern channel has a continuous depth of 16 feet at low water spring tides. The least width at 14 feet below datum is 700 feet, whereas in May last it was 330 feet only

The centre of the bar has not, since May 1865, moved to seaward

The low water mark on the east face of deep water point has receded about 390 feet

Both of the channels to the upper harbour have improved, the west one particularly being much more direct

Again, it appears from a Report of the Master Attendant, Kurrachee (Captain Giles), dated 23rd August, 1864, that the bar had again greatly silted up and considerably extended to the south-eastward.

Thus the evidence as to deterioration of the depth of water over the bar is conclusive.

But the material of which the bar is formed has also altered. It is now much coarser than formerly, heavy instead of very light sand.*

This is a natural result of the increased velocity of the flood and ebb tides, of which the maximum is now 5 knots against $2\frac{1}{2}$ previous to the construction of the groyne. Mr Parkes was asked by the Bombay Government whether the accumulation on the bar *during the monsoon* is due to material brought down from the harbour or from the sea. "*Neither*," says Mr. Parkes, "but simply a redistribution of the material, already existing in the bar itself." Now, the monsoon of 1863 left the bar, whatever its composition was, in a worse state than it was before it came on, and from the description of its state in January and April, 1864, it is evident that the action of the non-monsoon time does not by any means altogether undo the monsoon action.†

A comparison of the sections in April 1863 and April 1864, shows also a serious decrease in the area of the outer sections.

It is undoubted that in the year ending April 1864, the final effect on the bar was deterioration, as respects depth of water, and, for certainly 8 out of 12 months, of the material of which it is composed.

The paper shows that a survey of the state of the bar and the eastern channel was taken in May and September 1864, and January and May 1865, but as the result is not mentioned, it may be fairly concluded that it was not satisfactory, and that Captain Giles's unfavorable Report of August 1864 was confirmed.‡

Satisfied of the insufficiency of the measures which had been carried

* Letter of 24th March, 1866, from Superintendent, forwards specimens of the sand, showing that the fine sand had again taken the place of the coarse on lines 28, 32, 36 of sections. The Superintendent states that recent tidal observations which he has made tend to show that this alteration is not to be ascribed to a diminution of the strength of the current over the bar.—T. D., 20th June, 1866.

† The greatest velocity of ebb tide in Kurrachee harbour on record is 4.34 miles an hour. This was 1 hour 47 minutes after the beginning of ebb. The rise of tides was 8 feet 7 inches, and it was observed just off deep water point between 15 and 16A sections. This was on 25th February last, when the east pier had reached a length of 860 feet.

‡ Since this review was prepared the surveys have been received. They show that—

In May 1864, the west channel had 11 feet of water, the east channel 15 feet and very narrow.

out, the Bombay Government on the 28th March, 1864, after receipt of Mr Parkes' 2nd Report, ordered the carrying out of the east pier in continuation of the Keamari groyne, and preliminary steps towards the removal of deep water point, and the construction of the Manora breakwater

By this time the east pier must be nearly, if not quite, finished *

The construction of the Keamari groyne, Colonel Tremenheere argues, has resulted in the whole amount of the water required to fill the harbour being necessarily drawn from the disturbed and broken water in almost immediate vicinity to the line of breakers on the bar, and from the coast current * * * scouring the sea bottom "This water, very heavily laden with sand during the monsoon is swept into the harbour by a current varying from 3 to 6 knots an hour, where the greater portion of the sand is deposited as the velocity is checked, and it gets within the sheltered area." The further extension of this groyne in the east pier "can only result in the more rapid deterioration of the harbour, as the flood-tide would then be drawn from the immediate vicinity of the surf"†

Once deposited, this sand is not scoured out again, as the lifting power of the breakers is wanting within the harbour

Colonel Tremenheere very appositely remarks,—"There is nothing to indicate that the injurious effects upon the bar and entrance channels

In September 1864, the west channel had 11 feet of water, the east channel 17 feet, and the bar had lengthened

In January 1865, the west channel had 11 feet of water, the east channel 17 feet

In May 1865, the west channel had 11 feet of water, the east channel 15 feet, the east pier being nearly finished

In my annual Report of operations for 1864 65, submitted to Government on 25th July last, I wrote as follows —

"Paragraph 42 It appears therefore that during the fair season, and particularly since January last, the scour increased by the progress of the east pier, had an effect on the bar which promises most favorably for the success of the works, if that scour can only be allowed to remain in force during a time sufficient to enable it to work completely through the bar The south west monsoon will doubtless counteract all the good which has been done during the fair season, and will leave the entrance in a worse state than it was at the close of last monsoon, for the tendency of the present scour in its efforts to break through the bar," &c &c

Last monsoon was here a very light one, and the consequence was that the September and October surveys showed the effect of the scour working without the usual serious interruption from the south west monsoon That is, the bar was narrower than in May

This appears to me to be the best possible practical proof of what might be expected from the execution of the Manora breakwater

* The tipping of stone for the east pier was finished on the 24th August last, since that time the finishing of the slopes has been in progress This will be completed in about a week from this time

† The greatest velocity of flood tide on record is 2 95 miles an hour. This was on the 28th February last, just about deep water point, between 13 and 15 sections, 2 hours and 50 minutes before high water Rise of tide 8 feet It is possible that there may have been tides of greater velocity than this which have not been calculated, and this will also refer to my remark in page 59

* * * * * were ever contemplated by either Mr Walker or by Mr Parkes "

The latter, in his report dated 28th October, 1863, paragraph 33, states, that if some warning as to the possibility of a temporary injury to navigation had been on record, the evil might to some extent at least have been prevented by precautions in the execution

Clearly the result was not anticipated by any one but Colonel Tremenheere, who considers that "the design has been in violation of the principle which should have been kept in mind in dealing with a harbour upon a shallow and sandy coast, viz, to avoid the construction of works which would have the effect of increasing the force of either the flood or the ebb-tides "

This "principle" is put in connection with an opinion of Mr Rendell's, as if it had been an *axiom* of his

The present state of the works, their objects, their effects, and the objections taken to them by Colonel Tremenheere, having been stated, it will be as well to note their cost

The revised estimates, for what may be called the first series of works, amount to Rupees 26,15,747.*

I feel pretty sure, however, that those given by me as the maxima may be safely assumed to be so

The tables alluded to in my remarks on No 31 will enable an opinion to be formed as to whether there is any deposit, "as the velocity is checked, and when it gets within the sheltered area " May 1865 survey compared with that of January 1858 shows from 1 to 27 sections, both inclusive, a decrease altogether of 1,598 superficial feet, against an increase of 86,948 superficial feet

* The revised estimates for the original works submitted by me were as follows —

	RS
Keamari groyne,	3,63,980
Napier mole bridge,	5,61,023
Native jetty,	4,84,246
New channel,	7,56,241
Chinna creek embankment,	1,98,440
Total Rs.,	23,63,930

26,15,747
23,63,930 or less than amount given above by Rs 2,51,817
2,51,817

The Kurrachee Harbour Works Establishment up to end of October 1865, which was the date by which it was at the time of submitting revised estimates thought that the works would be completed, amounted to Rs 2,52,421 It appears probable, therefore, that in the amounts given as the estimates the cost of establishments has been included

The note in page 63 would lead to the supposition that the expenditure of nearly a quarter of a million did not include any establishment charges, whereas from the above it would appear that more than 2½ lakhs have been included on that account The revised estimates were submitted on the 8th December, 1864 Up to the 30th November, 1864, a sum of Rs 1,35,902, including charges for plant, had been expended on the Chinna creek stoppage work, not Rs 6,000, as stated above. The Chinnà creek embankment was then in such a state that from two to three months' work would have sufficed to complete it, nearly two-thirds of the estimate had been expended upon it

The Native jetty has nothing to do with the harbour improvements, though doubtless the position has been selected so as to work into the diversion channel of the Chinna creek at the bend. It may, however, be regarded purely as a convenience of the port.

Thus the estimates of the harbour improvement works proper may be reduced to about 21 lakhs, and as only about Rs 6,000 have been spent on the Chinna creek embankment, the estimates for the works really carried out or in progress, are still further reduced to about $18\frac{3}{4}$ lakhs, nearly the whole of which must have been completed.

The total expenditure up to the end of 1864-65, as entered in the Budget estimate for 1865-66, is upwards of $27\frac{3}{4}$ lakhs, or, omitting the Native jetty, $22\frac{1}{2}$ lakhs. The difference between this sum and $18\frac{3}{4}$ lakhs is probably due to cost of plant, which is charged off proportionably in the estimates of the various works, and to an outlay of about $1\frac{1}{2}$ lakhs on the second series of works, consisting of—

	RS.
The east pier, estimated at	1,81,499
The Manora breakwater, at	11,92,362
The removal of Deep-Water Point, ...	3,05,842
Total Rs, . ..	16,79,703

and chiefly on the first of these three works, as, pending Mr Parkes' approval to the designs, &c, a tramway to Manora point is the only portion of the others put in hand.

Thus on the works of pure improvement the total outlay is, including establishment, close upon a quarter of a million sterling by this time, and, saving favorable action on the bar that may have recently followed on the construction of the east pier, the results have been decided deterioration.*

The mistake is no doubt owing to a copy of the former estimate for this work, which was submitted by Mr Price in February 1863, having being forwarded with the revised estimates, with changes only made on account of alterations for plant, &c, in charge. The state of the work at that time was, however, explained in the specification.

* The recent favorable action on the bar has already been noticed. In addition to this, great benefit has been derived by the mercantile community from the formation of the new channel west of the mole.

The carrying out of the Keamari groyne and east pier has also had the effect of cutting away Deep-water Point to a very great extent already, and will do so still more. This improvement is, of itself, of very great importance, although as yet the quantity removed has not been sufficient to affect the bar to any great extent.

The improvement in the upper harbour has been very considerable.

Before the works were commenced, the eastern channel to Keamari was not 14 feet deep at low

Looking to this result so unpredicted and unexpected by the projector, to the change in the order of carrying out the works, the Chinna creek closure, which should in Mr Walker's opinion have been carried out first, having been postponed (a measure which it should be noted was recommended by the consistent opponent of these works, Colonel Tremenheere, in his letter of 29th July, 1863), to the great excess in the revised over the original estimates (cent. per cent), a small portion only of which is due to the rise in rates (one of the revised estimates, that for the new channel, being four and a half times the original), and to the want of confidence exhibited by Mr Parkes himself in the sufficiency of the additional works now recommended to be carried out, to ensure ultimate success as evidenced by the following extract from Mr Parkes' second Report —"I would beg to state, however, that they do not pretend to be final The works are of an essentially tentative kind I have confidence in their being in the right direction, but their final extent must depend on observation of their effects This remark applies obviously to the two latter recommendations (the removal of Deep-water Point and the construction of the eastern pier). With regard to the first, the breakwater I recommend the whole length, because I do not think any less length will give the requisite amount of shelter Indeed, if I were making a new design with my present knowledge of the respective actions of scour and breakers, I should probably show a greater length of breakwater, and I think it possible such greater length may be found desirable This will, however, be tested by experience of the length now proposed," it would seem that Colonel Tremenheere's suggestion (made in 1863) that the whole subject should be "submitted for the consideration of some one of undoubted" scientific acquirements in England, upon whose opinion

water There is now a continuous channel at 15 feet, and at 14 feet it is very straight, and in the the narrowest part 325 feet wide

The 15 feet channel is, except in one place (on No 6 section line) where it is only 125 feet wide, almost as wide as 14 feet Formerly, as shown by the survey of 1857 58, the deepest contour cut by No 1 section line was 21 feet, now it is 24 feet

Previous to the Keamari groyne being carried out, the cross current which came from the south Keamari island caused a very strong eddy in the upper anchorage, and several accidents from collisions resulted in consequence It was than necessary to moor vessels very far apart, as they did not swing together Since the Keamari groyne was carried out, the upper anchorage has been all that could be desired, and vessels can lie very much closer than formerly

These advantages, together with the great weakening of the bar, have therefore to be considered as the favorable results of that portion of Mr Walker's design which has yet been carried out

On the other hand, there is the great lengthening of the bar, without which it appears to me that the designer could not have expected to form a new and direct channel through the bar

full reliance may be "placed," was not unreasonable. It was, however, rejected by the Bombay Government, though supported by His Excellency Sir W Mansfield, in his Minute of 16th August, 1863 *

Colonel Tremenheere in his report, dated May 19th, 1864, discusses the probable effects of the Manora breakwater, and condemns not only the design of Mr Walker adopted by Mr Parkes, as not affording any effectual shelter to that part of the bar which it is desired to scour away, but looks upon any breakwater at this point being of any use as highly problematical

Colonel Tremenheere's general conclusions will be found briefly put in the Report just quoted, Nos 1, 4 and 7, are expressions of opinion, Nos. 2, 3, 5 and 6, are statements of fact They are as follows —

"1st —The peculiar position of the harbour, with reference to the monsoon surf acting on the shallow coast has not hitherto met with sufficient consideration

"2nd —The increased velocity given to the tides by the construction of the groyne has increased the size and the height of the bar instead of opening a passage through it or scouring it into deeper water, as was intended

"3rd —The tidal water to fill the harbour being now drawn from the vicinity of the breakers on the bar, and carried at a high velocity through a narrow deep funnel, is much more laden with sand, silt, and mud, than it was formerly; and the amount of such sedimentary matter brought in by the flood during the monsoon, much exceeds what can be lifted and carried out by the ebb-tides, so that the amount of deposit within the harbour must annually increase

4th —The result of extending the groyne still further must be to draw water during the flood-tide still more heavily charged with sand, and to cause still more rapid injury to the harbour

"5th.—The bar has increased both in length, and width and height since the works were commenced, and the depth of water in the entrance channels has been materially reduced

"6th —We find both within and outside the harbour the preservation of the general form combined with a change of material from very light to heavy sand, a result which it should be an Engineer's object to avoid.

* In the case of the Chinna creek stoppage, Mr Walker estimated for closing a creek 1,280 feet wide When the time came to carry out the work, that creek, from causes which could not have been foreseen, was 2,780 feet wide

"7th —The proposed breakwater would not afford any effectual shelter to that part of the bar which Mr Parkes wishes to scour away, and it is very improbable that a deep channel could be formed in that direction "

The following paragraphs of a Memorandum by the Secretary to the Government of Bombay, in the Public Works Department, Lieutenant-Colonel Kennedy, appear worthy of consideration —

"12 —Its position may, however, be altered so as to give more protection, and it may, as Mr Parkes thinks it may be necessary to do, be lengthened, if the extent now proposed is found insufficient

"13 —Colonel Tremenheere admits that the strong scour has improved the bar 'as long as it is under the protection of Manora;' and the obvious thing to do is, prolong Manora, *i. e*, construct the breakwater so that the protection which has acted beneficially at the other end of the bar, may be extended to the more important part of the shoal.

"14 —The weakest points of Colonel Tremenheere's argument on the whole question are those I think, which he directs against the Manora breakwater He admits, paragraph 37, that a breakwater sufficiently long to subtend an angle 30° between the line of surf and the portion of the bar to be protected would have an appreciable effect, but adds, that to secure this, double the length of work proposed by Mr Walker would be required.

"15 —A slight alteration, however, in the direction of the breakwater would secure the amount of protection contemplated, or even more, without additional length

"16 —Without the breakwater, however, I believe a sufficiently deep channel may be secured at the entrance to the harbour, by the simple prolongation of the Keamari groyne, and but for secondary effects I think this would be the only work necessary

"17 —These secondary effects are—

"1st —The groyne, if too far extended, would reflect the monsoon waves into the harbour, and,

"2nd.—It would leave untouched, or rather give increased force to Colonel Tremenheere's main objection that the flood is derived from a disturbed and silt-laden source

"18 —The simple extension of the Keamari groyne would therefore probably give a sufficiently deep entrance channel to an unquiet, and probably in the course of time, a very greatly circumscribed, harbour "

Colonel Tremenheere has been a consistent opponent of the scheme ever since he has been connected with the supervision of its execution, and, as far as the papers show, his opposition is not based on his having originated or adopted an alternative scheme The project was also condemned by an officer of the Indian Navy, Lieutenant Taylor Both these officers, one acknowledged by the Government of Bombay to be an "able and thoroughly conscientious" engineer, the other "a well-known" surveyor, and well acquainted with the shores of Sindh and Cutch, agreed so far in opinion that the works had been undertaken on insufficient data

The late Governor of Bombay, Sir G Clerk, recorded (probably in 1862) a Minute which was forwarded to Colonel Tremenheere for information, in which the following opinion was stated .—" I am not sanguine that as far as scouring the harbour is concerned, which is the principal object of the works, they will have the effect which is anticipated of them, but at the advanced stage which I find they have now reached, there is, I apprehend, no alternative except to complete them thoroughly "

The Government of Bombay has since returned entirely to its previous confidence in Mr. Walker's opinion, and has lately trusted equally to Mr. Parkes.

The scheme is supported by a phalanx of engineers and others of local note, including General Scott, Colonels Turner and Kennedy, Captain Hill, Mr Hardy Wells, C E, and Captain Giles, I N., the Master Attendant of the port But, of these, Colonel Turner and Captain Giles are the only officers who can pretend to the same or more local knowledge than Colonel Tremenheere The designer of the works never visited the place, and Mr Parkes never saw a monsoon there His Excellency, the present Governor of Bombay, was instrumental in the projection of the works as Commissioner of Sind.

But it should be prominently noticed that Mr Walker's scheme has not been adhered to The work that should have been first carried out, the closure of the Chinna creek and its diversion through the harbour, not only not having yet been executed, but having been postponed, it may be said almost indefinitely, for although it is avowedly "deferred until the regimen of the harbour current has been definitely attained on the completion of the other works," and in Bombay Despatch, No. 37 of 1865, the Secretary of State is asked for Mr. Parkes' opinion as to cutting

through the mole, so as to add the Chinna creek waters to the harbour; it cannot be expected that there will, when the regimen is attained, be much, if any reduction in the velocity (maximum, 5 knots) attained by the tides since the construction of the Keamari groyne, whilst all agree that the introduction of the Chinna creek waters into the harbour will add to the velocity of the tides, so that it is more than probable that postponement may still be the order of the day, even after the regimen has been attained *

The following note to Sir W Mansfield's Minute of the 16th August, 1863, should certainly engage attention before this closure is permitted, independently of Colonel Tremenheere's anticipations as to its action on the bar

"When the Chinna creek shall have been closed, which I suppose will largely increase the already formidable force of the ebb-tide, where are the ships to lie? Can their moorings be laid in a tideway running as fast as Alderney race?"

Looking at the question from a distance, and from all points of view, with the later experience of the effect of the works before us, and with the further prosecution of the second series of works at an outlay estimated at 15 lakhs (quite untrustworthy in Colonel Tremenheere's opinion), about to be decided upon, it seems to be a measure of the most ordinary as well as of the most obvious prudence to adopt the course suggested two years ago by Colonel Tremenheere, and, Mr Walker being dead, to submit the whole question to the unbiassed opinion of some independent engineering authority of eminence in England

The Government of India has expressly stated to the Secretary of State in Despatch, No. 47, of July 1st, 1864, that it is not necessary for it to comment on the engineering character of this project. Tidal hydraulics constitute the most difficult branch of engineering, and it is well to leave the present scheme with the Civil Engineers of England by whom it has been projected.

No 23, dated 17th April, 1866.

Letter from Secretary of State for India in answer to the above.

I am now in a position to reply to your Excellency's Despatches, Nos.

* In remarks on paragraphs 46 and 51, it has been already shown that the velocities of both flood and tides are not so great as they have been supposed to be.

122 and 157, of 18th September and 15th December last, regarding the Kurrachee Harbour Improvements Works

In accordance with the suggestion contained in the earlier of these Despatches, Sir C Wood caused all the papers on the subject to be placed before Messrs D. and T. Stevenson, of Edinburgh, whose residence at a distance from London was regarded as rendering them on the whole more suitable referees in this particular case, than some other harbour engineers might have been, who, though of equal professional eminence, had formerly been brought more closely into contact with the late Mr Walker

The questions upon which Messrs Stevenson's opinion was asked were the following —

1st—The validity or otherwise of Colonel Tremenheere's objections, and the consequent expediency or otherwise of stopping the works

2nd—The amount of probability, on general considerations, that Mr Walker's plans, if prosecuted to completion, will effect an improvement of the harbour commensurate with their cost

The referees were also distinctly informed that, though they would not be precluded from offering observations upon any matters of detail which might occur to them, it was not desired that they should submit a fresh scheme, either in substitution for, or even materially in amendment of, Mr. Walker's The reference was thus restricted, because it was felt that the production of a new or amended plan would be sure to prolong, instead of putting an end to, discussion, whereas what was wanted was an authoritative decision on which to base some plan for future procedure

Messrs Stevenson's reply, is so far satisfactory that it completely answers the purpose for which it was asked. The opinion it expresses is clear and decided, and is evidently the result of mature consideration, but it is at the same time altogether unfavorable to the principles, as well as to the details, of Mr Walker's design This result is greatly to be regretted, for it implies that the large expenditure, amounting certainly to not less than a quarter of a million, which has during the last few years been incurred on account of the Kurrachee Harbour Works, has been little better than wasted There seems, however, to be no alternative but to accept the conclusion at which Messrs. Stevenson have arrived, and temporarily, at least, to shape our course in accordance with it. Works condemned on such authority, cannot be allowed to proceed at an expense which nothing but a well grounded confidence in their eventual success

would justify, and I shall accordingly instruct the Government of Bombay at once to stop all operations not absolutely necessary to give stability to the portions of work already done.

I am anxious, however, that the effect of these incomplete works should be carefully watched, for it is possible that they may prove more useful than Messrs. Stevenson's report would give reason to expect In questions of harbour improvement, where the most careful calculations are liable to error from local peculiarities that cannot be foreseen, the best judges are frequently at fault, and it is not impossible that, in spite of adverse anticipations, the action of the Keamari groyne may ultimately prove beneficial to the port, and may even serve to suggest how further improvement may be made.

Messrs Stevenson's letter, enclosed in the above

We have the honor to acknowledge receipt of the instructions from the Secretary of State for India, of date 13th December last, relative to Kurrachee harbour —

In accordance with the remit made to us, we have most carefully perused the various documents sent for our information, embracing in particular Mr Walker's reports of 8th September, 1856, and 28th October, 1858, Mr Parkes' reports of 5th June, 1858, 28th October, 1863, and 15th March, 1864, Colonel Tremenheere's reports of 19th May, 1864, 30th January, 1865, and 15th February, 1865, and Mr Parkes' report of 29th September, 1865, upon Colonel Tremenheere's observations We have examined the various charts of the locality that have been sent to us for our information, and after fully considering the whole of the information thus afforded, we transmitted our opinions in draft to Mr Parkes and Colonel Tremenheere for their observations, which, having received and further considered, we now beg leave to submit the following report for the consideration of the Indian Government

Our first duty in this reference is to express our conviction of the importance of the subject submitted for our opinion. A design of works for the improvement of Kurrachee harbour was prepared by the late eminent James Walker in 1858 That design has, after due consideration, been adopted by Mr Parkes, who has the advantage of personal knowledge of the locality, and has most clearly and ably expressed his views in his several reports. The work so designed and adopted has been, to some extent,

executed, but it is admitted on both sides that up to March 1864, no permanently favorable results have followed Colonel Tremenheere, who possesses a most intimate knowledge of the locality, and has carefully watched the works during their progress, has, in a very able statement, called in question not only the correctness of Mr Walker's information as to the physical state of the harbour, but also the soundness of his views as regards the works he proposes for its improvement We have, therefore, in repeating our conviction of the importance of the subject, to express our feeling of responsibility in dealing with the able and lucid, but yet antagonistic statements of Mr Parkes and Colonel Tremenheere, and above all, in laying the conclusion at which we have arrived before the Indian Government

The scheme of works, as proposed by Mr Walker, included,—1st, The Keamari groyne, on the east side of the harbour, extending from Keamari to near Manora head, a distance of 7,400 feet, 2nd, The "Manora breakwater," on the west side, extending for a distance of 1,500 feet from Manora head, 3rd, The closing of the Chinna creek, and, 4th, The formation of extensive docks and basins in the upper part of the harbour

The two first-named works were intended to effect the "deepening the water over the bar," which, Mr Walker states, was the "desideratum" to which his "attention was particularly directed" by the Government

On a careful perusal of Mr. Walker's first report, it appears to us that originally he had not held a decided opinion as to the origin of the "bar," as it has been called, which is situated at the mouth of the harbour, for the first says, "the bar is, as has been stated in other reports, the result of the current from the harbour meeting the coast tide, its velocity being checked, and rendered insufficient to support and carry out into the tideway the matter which is brought in front of the harbour, apparently from the westward, by the heavy seas during the southerly gales," and again, he says, "it matters but little whether the sand which forms the bar is brought down by the land floods or is brought in by the waves and currents from the sea, or (which is the most probable case) brought round Manora point from the westward and lodged at the harbour's mouth. Its pointing eastward, or in the direction of the flowing coast tide and of the prevailing winds, appears to show that it is formed by heavy seas or by the tide when in that direction"

It appears from subsequent reports of Mr Walker and Mr Parkes, that ultimately Mr Walker attributed the bar to what, beyond all doubt, is its *true* and *only* origin, namely the action of the waves in throwing up the sand, and thus tending to form a continuous line of beach across the mouth of the harbour

But, whatever views may have been held as to this, the ultimate conclusion of the engineers was, that in order to deepen the entrance, the place termed "the bar" must be protected from the action of the sea In this view we entirely concur As a general principle, we have, ever since 1842, when we had occasion to examine somewhat narrowly the characteristics of the Firth of Dornoch in Sutherlandshire, insisted that such bars or shallows as that at Kurrachee could not be improved by any design that did not include works for *effectual* protection from the sea, and, acting on this principle, we have made our designs, and given our advice, with reference to many harbour improvements

As the advancement of the harbour of Kurrachee appears, from the documents laid before us, to be dependent on getting increased permanent depth of water at its entrance, it is obvious that all questions with reference to internal works may safely be considered as in abeyance until the improvement of the entrance is secured, and, therefore we propose *to confine our report to that all-important question.*

The chief work which has as yet been executed is the extension of the groyne from Kurrachee to opposite Deep-water Point, a distance of 2,467 yards From the evidence contained in the reports, it appears that the first effect of this work, as ascertained in 1863, was to increase the sectional area in the upper part of the channel, where it is confined by the groyne, and was so far beneficial; but that after the monsoon of 1863, with its winds and waves, had passed away, the sectional area was again reduced, and the channel was restored to pretty much its former condition in 1858, previous to the commencement of the works During the same period it appears that the bar has also undergone certain changes, but it cannot be said that any permanent improvement, either of the inner channel, or of the bar, has been effected

Mr Parkes admits these adverse circumstances, but suspends his conclusion as to the cause, and concludes that the effect is merely "incidental" and "probably temporary," and will disappear as the design is carried out."

Colonel Tremenheere, on the other hand, ascribes the decrease of sectional area of the inner channel to the increased current due to the formation of the groyne carrying off the sand raised by the waves acting in the shoal water, and depositing it in the upper reaches, an action which he says will increase as the groyne is further extended, while he attributes the unimproved state of the bar to the inadequacy of the increased scour, opposed as it is by the monsoon waves, to produce any beneficial effect

We think it is unnecessary to enter into details as to what has taken place in consequence of the works that have been executed. Mr Parkes admits, as we have already said, certain adverse consequences, though he expresses himself as confident that when the work is completed, in terms of Mr. Walker's design, the evils complained of will be removed, and therefore it seems to us that the settlement of the question in dispute may now be safely determined by a careful consideration of the following *conclusion* and *question*

The conclusion for consideration which has been arrived at, by both Mr. Parkes and Colonel Tremenheere, is that the works cannot prove successful unless the shoal water at the entrance to the harbour is protected from the waves during the monsoon

The question for consideration is, will the works, as designed by Mr. Walker, effect this object?

With reference, to the conclusion, we entirely agree with Mr Parkes and Colonel Tremenheere that protection is absolutely required, and we hold this opinion, we suspect, even more strongly than these gentlemen, although Mr Parkes, in his report of 15th March, 1864, urges very strongly the necessity of constructing the Manora breakwater, "to the extent and in the line laid down by Mr Walker So important, indeed, do we regard the question of protection, that we should have been disposed to consider the sea works for that purpose of *primary* importance, and to have postponed all internal works until the outer work had been executed and its effects tested by actual trial

The question, as to whether the works contemplated will effect the object in view, we regret to be obliged to answer in the negative We do not think that a breakwater of 1,500 feet long, projected from Manora head, more especially if it is laid out in the line proposed by Mr. Walker, will either shelter the bar or remove the evil.

We are sorry to be obliged to come to this adverse conclusion, and in order to account for the difference between Mr. Walker's opinion and our own on this important question, we feel bound to repeat that we do not think Mr Walker, in forming his original design had sufficiently adverted to the following facts.—First, that the sea is the true cause of the accumulation at the entrance to Kurrachee harbour, Second, that the accumulation is of great amount, extending for a distance of three quarters of a mile from Manora head to the eastward in front of the harbour, while the bar in the navigable channel is not a sudden diminution of depth, but a very gradual shoaling and, Third, that the water in the bay itself is also very shoal, so that, in point of fact, in the present navigable channel, there is no decided bar, properly so called Had these facts been fully considered by Mr Walker, we think that he could hardly have arrived at the conclusion, that after the execution of the proposed works," at least 20 feet at low-water of spring tides, with an ample width of entrance sheltered from the worst winds may be depended on "* It further appears to us, that when Mr Walker proposed to remedy the evil by means of the proposed groyne and breakwater, he had relied on the increased scour due to the confined channel and the addition of the water gained by shutting up the Chinna channel to remedy the evil, and had not sufficiently adverted to the action of the sea, and this may account for the very inadequate protection from the waves which the Manora breakwater would afford That work might check the movement of sand along the beach, if that were necessary, but could not shelter the extensive tract of sand bank which forms what has been termed the bar of the harbour Unless this extensive sandbank is thrown completely under shelter, we confess that we cannot hold out the hope of any *permanent* improvement of the channel, and to effect this requisite amount of shelter, the sea works must necessarily be designed on a much more extensive scale than seems to have been contemplated by Mr. Walker It is, perhaps, right to add that, even if constructed on such an enlarged design, the generally shallow water in the channel and bay lead us to regard it as doubtful whether the full depth of water expected by Mr. Walker could be permanently maintained.

The remit made to us does not call for any expression of our views as to the present state of Kurrachee harbour or works for its improvement,

* Mr. Walker's Report, 28th October 1865.

and, therefore, we abstain from offering any opinion on that subject. According to our understanding of the advice sought from us, it is restricted simply to the question, whether the views of Mr. Walker and Mr. Parkes, or the antagonistic views of Colonel Tremenheere, are correct; and, without committing ourselves in every respect to the opinions of Colonel Tremenheere, we have no hesitation in reporting that, on the evidence laid before us, we have come to the conclusion that Colonel Tremenheere's fears as to the ultimate success of the design of Mr. Walker are well founded.

P. S.—After the foregoing Report was drafted, we received, for our further consideration, the letter from the Public Works Department of Bombay, of 21st December, 1865, communicating the Memorandum and relative Plans by Lieutenant-Colonel Fife, R. E., of the 21st November, 1865. Colonel Fife, in his Memorandum, says, "the present condition of the harbour is very unfortunate indeed for the shipping, the entrance over the bar being not only smaller than it used to be, but also excessively awkward." This further evidence tends to confirm the conclusion which we drew from the information submitted to us that no permanent improvement has as yet been effected by the works that have been executed. Colonel Fife suggests, "in order to give the existing works a trial, to see whether, they can maintain a channel opposite the harbour," that harrowing or raking should be tried on the bar, and that a groyne should be projected from Deep-water Point, in order to give the current a set to the opposite side. The remit made to us having been restricted to the ultimate effect of the works now in progress we have not entered on the consideration of the experimental measures suggested by Colonel Fife.

No. 532c, dated 14th June, 1866.

From the Government of India to the Government of Bombay.

The Secretary of State, acting on the opinion of Messrs. D. and T. Stevenson, harbour engineers of Edinburgh, which is adverse to the principles and details of the late Mr. Walker's design for the improvement of the Kurrachee harbour, directs the immediate stoppage of all the works in progress except those which are obviously calculated to serve some purpose of public utility, independent of the general improvement of the port, or which cannot be left in their present state without doing positive

harm The Secretary of State is anxious, however, that the effect of the incomplete works should be carefully watched, and he is desirous of being kept informed of the state of the harbour, as he deems it not impossible that the action of the Keamari groyne may ultimately prove beneficial to the port, and may serve to suggest how further improvement may be made

The Government of Bombay will no doubt have received this confirmation of the unfavorable opinion of the works entertained by Colonel Tremenheere, the Chief Engineer in Sind, with the same regret as the Government of India has The Governor General in Council recognizes the importance of improving the harbour of Kurrachee, but a very large sum of money has been spent with little result, and it is unquestionably the prudent course to suspend operations until a project which shall command general confidence shall have been obtained The instructions of Her Majesty's Government should therefore receive early attention, and it is due to Colonel Tremenheere to place on record an acknowledgment of the faithful and conscientious manner in which that officer discharged an unpleasant and invidious duty in persistently pressing his objections to the design of the works.

No CLXXVI

PALAMPORE CHURCH—KANGRA.

By E. Martin, Esq, C.E., *Executive Engineer*

A reference to the drawings will show that this Church as designed, possesses every canonical requisite for its sacred purpose

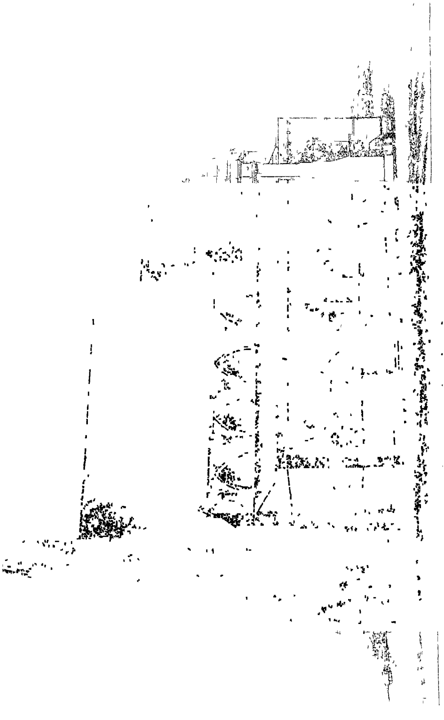
It consists of a nave and two side or verandah aisles in the second bay from the west end in each of these aisles is placed an entrance door, and a porch is also provided in the centre of the west end of the building

A stone font, sufficiently large to admit of immersion, will be placed within an enclosed Baptistry, composed of an open tracery-carved screen at the western end of the south aisle, and will be furnished with an appropriate canopy

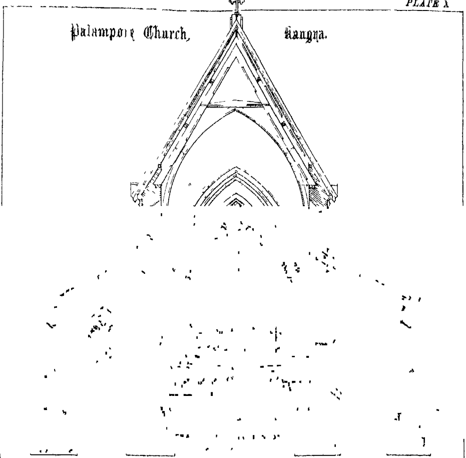
A good deep chancel has been given, furnished with communion table, altar chairs and kneeling stools, behind the altar will be a traceried reredos, the panels of which will be ornamented with Christian emblems, the painted windows over the reredos will be filled with stained glass with subjects occasionally introduced in small medallion and quatrefoils, the chancel rail will also be of carved tracery, with a two leaved door in the middle, opening with brass strap hinges.

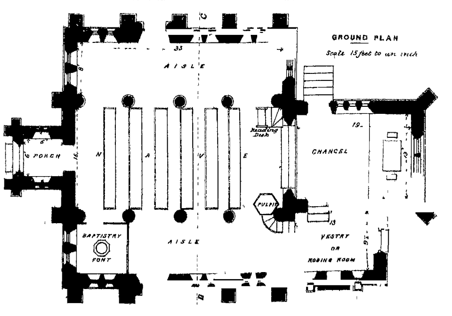
A vestry or robing room fitted with a shelved locker for the Church records is provided at the eastern end of the South aisles, having a door communicating with the chancel and a small stair leading directly from the vestry to the pulpit

The Reading Desk is placed at the Epistle or north side of the Church, while the pulpit is situated at the south or Gospel side.



Palampore Church, Kangra.





Nineteen inches is the width of each sitting provided for in English Churches, but as it was deemed advisable to allow a more liberal space in this country, two feet wide have been given for each adult The number of persons the Church is calculated to accommodate at this computation, (using only the nave and leaving the side aisles vacant), is forty-eight, but this number can at any time be increased if found necessary, as the aisles would easily hold at least fifty, additional sittings, (allowing for passages), bringing the total obtainable accommodation up to one hundred souls At present it is proposed to pew the nave only

This Church is capable of extension at the west end and with a view to such contingency, and to secure a cool comfortable building, it was designed sufficiently lofty to admit of an increase in length without becoming disproportioned, distorted or made to look unsightly, for the same reasons a fully proportioned chancel was given

A Belfry, sufficiently lofty to form a conspicuous feature in the design, has been placed on the apex of the west gable of the nave roof. Ample ventilation will be secured through the doors, windows and ridge The clerestory windows will be made to revolve on pivots, and an open ridge will be provided

The Church is designed in the Early English style of Eclesiastical architecture, period 13th century, and in order to meet the funds at the disposal of the promoters of the project, the designs have been drawn up with a view to economy, all superfluous ornamentation, which would lead to considerable expenditure having been carefully excluded, the aim has been to include in the arrangement of this building all the essentials of a Church, nave, southern porch, font, chancel, aisles, pulpit, reredos, &c., and to endeavour to design all these various features in a correct style, without curtailment or modification and of strictly Eclesiastical character.

Specification

Excavation for Foundations —The earth to be excavated until a thoroughly firm and secure foundation is obtained, all inequalities to be dressed off and the whole made perfectly level, both longitudinally and transversely

Concrete in Foundation.—A bed of concrete 12 inches deep, composed of two parts of broken stone and one part of mortar to be laid under all walls;

the stone to be broken to about the size of a pigeon's egg, or capable of passing through a ring $1\frac{1}{2}$ inch diameter, the mortar to be one part of freshly burnt stone lime and two parts of soorkee, the whole to be mixed by hand in proportions of one part mortar to two parts broken stone, and thrown into the foundations from a height of at least 10 feet, and to be well watered and rammed in 6-inch layers

Masonry in Foundation—The foundations to be constructed of the best rubble masonry properly crossed and bonded, a thorough bond-stone, extending the full thickness of the wall, to occur in every course at distances of not more than 6 feet apart The work to be carried up in 12-inch courses, the largest stones to be placed at the bottom, all internal points in every course to be grouted, and the interstices to be filled with spalls and mortar, the masonry to be carried up uniformly and each course to be carefully levelled

Masonry in Superstructure—The body of the work to be uncoursed rubble masonry, and the string courses, arches, jambs of doors and windows, water tables, quoins, barge courses, hood or label mouldings, apex, kneelers, eaves courses, corbels, &c, to be of cut stone; the masonry to be the best of its kind, and to be very carefully executed to the dimensions and shape shown on drawings The walls to be truly vertical, and where connections with the ashlar dressings occur, the stones to be dressed to form close joints, no thick mortar joints to be allowed, and the backs of the walls to be left rough so as to form a key for the interior plastering The facing joints to be carefully raked out to a depth of at least 2 inches and pointed with fine mortar The mortar throughout the building, except for plastering, to be composed of one measure of freshly burnt stone lime and two measures of properly burnt soorkee, to be well and equally mixed and ground in a pug-mill and used as soon as possible after incorporation

Dressings.—All dressings and stone-cutting such as arches and jambs of doors and windows, tracery, barge courses, quoins, water tables, hood mouldings, kneelers, eaves courses, apex, pillars, caps, bases, corbels, &c., to be of the best and least porous stone procurable in the vicinity of the building, neatly chiselled and worked to the shapes and dimensions shown on plans and in accordance with detailed drawings which will be afterwards provided The stones to be as nearly as possible of a uniform color and free from unsightly stains, to be laid on their

natural beds, the joints being properly fitted and filled with mortar The arch stones to be carefully summered, (radiated), having hood mouldings cut on the solid stone and not let in or jointed, barge and string courses, water tables and buttresses, and all edges over which rain water will drip to be throated underneath, all corners, mouldings, chambers, cusps, &c &c, to be neatly and sharply cut and correctly shaped, interior corbels supporting roof timbers to be properly fixed and tail at least 15 inches into the wall, all dressings to be carefully bonded into the rubble masonry, the tails of all stones being left rough

Terraced Flooring —The earthwork under the floors to be thoroughly watered and rammed, to be covered with a layer of spalls 12 inches deep, over which will be spread $1\frac{1}{2}$ inches of fine concrete to be beaten down to 3 inches, and a finishing coat of fine mortar evenly gauged and properly levelled to be laid on the concrete

Plastering —All walls to be plastered interiorly with plaster composed of equal proportions of fresh burnt lime and soorkee, having 2 chittacks of goor and 2 chittacks of sunn well incorporated in every 3 feet of mortar The rubble faces only to be plastered, the cut stone work to be left uncovered, the surface of the plastering to be smoothly floated and finished with shell lime

Carpentry —All the timber used in the construction of the building to be of the best Deodar, (except for reredos, chancel rail and other tracery), to be evenly and squarely sawn, free from sap, large knots, shakes and other imperfections, and to be correctly worked to the dimensions and shapes shown on drawings The ends of all timbers entering the masonry to be charred and to receive a coat of tar to preserve them from insects and moisture, a clear space of $1\frac{1}{2}$ inches to be left around the ends of the timber so as to allow a free circulation of air The nave, chancel, aisles, porch, and vestry roofs to be constructed in accordance with the drawings, the curved ribs of nave roof to be made in two thicknesses firmly bolted together, the pieces to break joint and to be dressed so as to lie evenly, the collar brace to be stubtennoned into the principals, wrought-iron straps with bolts and nuts to be fixed where shown Diagonal boarding, rebated and beaded, to be nailed to the backs of the common rafters, the boarding will support the slating, the joints to receive a coat of red or white lead immediately before being connected, the roof timbers to be stop chamfered as shown on sections Seats as shown on plans, with elbows

3 inches and back framing $2\frac{1}{2}$ inches thick to be provided, the seats to be $1\frac{1}{2}$ inches thick with a half round nosing, resting on brackets 1 inch thick and about 4 feet apart, the back panelling to be $\frac{5}{8}$ inches thick, sloping book boards to be affixed to the back framing 6 inches wide and $\frac{1}{2}$ inch thick, having a retaining strip to prevent books slipping off The elbows and framing to be stop chamfered

A properly framed and constructed Pulpit with stairs to be made and fixed, the pedestal to rest in a cut stone base to be neatly finished

A Reading Desk to be provided, the front framing to be $2\frac{1}{2}$ inches thick and the elbows or sides to be 3 inches, to have a sloping book board with retaining strip and to be furnished with a kneeling stool

A properly framed and carved Chancel Rail with moulded capping to be fixed where shown, the door to be in two leaves, each 2 feet wide to be hung with large brass strap hinges and to be furnished with a brass hasp and staple

Reredos to be of seesum or toon wood properly framed and carved according to detailed drawings, which will be furnished hereafter Two sides of the Baptistry to be enclosed with open-work carved screens, the screens to be 8 feet high and finished according to detailed drawings, with doors at the east and north side

Enlarged detailed drawings will be necessary for all the wood work in the building as well as for the details of the stone cutting, these will be prepared in the event of the design being adopted.

The roof timbers and all interior carpentry to receive three coats of the best copal varnish, and all iron work such as roof straps and hinges of doors to be painted three coats of oil color finishing black

Slating —The slating to be that known as first class in this division, the slates to be nailed to the diagonal roof boarding, each slate being secured with three copper nails, two in the shoulder and one in the corner of the head, to have a 4-inch cover or overlap and the under eaves to run through

All hips, valleys, gutters, &c, to be rendered water tight with zinc flashings properly fixed

Bell —If funds will admit of it, a bell weighing from $2\frac{1}{2}$ to 3 cwt. to be provided and hung in the belfry, properly balanced and furnished with ringing wheel and all necessary cranks, sockets, gudgeons, ropes, &c.

ABSTRACT

c ft		
4,577	Masonry and concrete in foundations, including excavation, at Rs 16 per 100,	732
12,926	Masonry in superstructure complete, including stone cutting, at Rs 45 per 100, .. .	5,816
s ft		
3,458	Roofing complete, including wood work, slating, iron straps, zinc flashings, varnishing, &c , at Rs 60 per 100,	2,074
1,636	Flooring, at Rs 16 per 100, . .	262
5,427	Plastering, at Rs. 6 per 100,	325
761	Doors and windows complete with hinges, bolts, locks, varnishing, &c , at Rs 1-4, . ..	950
104	Reredos, at Rs 1, .	104
52	Chancel rail, at Rs 1, . .	52
128	Baptistry screen, at Rs 1, . .	128
48	Sittings, at Rs 4 for each person, .	192
1	Reading desk, at Rs 60, ...	60
1	Pulpit with stairs, at Rs 150, .. .	150
1	Font, at Rs 120,	120
1	Set, Altar table and chairs, at Rs 100,	100
		11,065
	Contingencies, at 5 per cent , ...	553
	Grand total of Estimate, Rs ,	11,618

EDWARD MARTIN, C E ,
Executive Engineer

No CLXXVII.

THE SHOLAPORE TANK

Report on a Proposed Tank, near Sholapore, in the Bombay Presidency.

From F D Campbell, Esq, Acting Executive Engineer, to Lieut.-Col. Fife, Superintending Engineer for Irrigation.

THE site of this lake is situated generally about 10 miles north of Sholapore, the village of Ekrookh being about the centre The proposed line of bund commences about half a mile to the westward of the village of Hyperga, on the south side of the Adeela river. It crosses that stream in a northerly direction, and terminates on the opposite spur, about three-fourths of a mile to the south-east of the Nizam village, Bogaum

It was at first intended to construct this bund entirely of earthwork, but as the cost amounted to as much as rupees 4,95,417, at your suggestion estimates were framed for two other kinds of bunds, the first consisting of a central masonry dam across the whole valley, flanked with partial slopes of earthwork to a height of two-thirds on the outside and one-third on the inside face In the second the above design was used only at the two ends, where soil was scarce, and the foundations good, the central portion consisting entirely of earthwork. As the estimate for the latter amounts only to rupees 4,80,981, it has been adopted, more especially as it is considered safer, and has a great many minor merits not possessed by the other designs The total length will be 7,200 feet, the masonry portions on the northern and southern ends

being respectively, 1,400 and 1,330 feet The maximum height of the earthwork over the centre of the stream will be 72 feet, or 7 feet above highest flood-line The slopes provided for are three to one on the waterside, and two to one on the outside face of the bund It has also been provided for in the estimate that the sandy material existing in the bed of the stream be excavated, and good soil be filled in instead The water slope of bund below flood-line is to be pitched with stones 2 feet in length The top of the masonry dam to be 3 feet above highest flood-line, and the dam to be surmounted by a parapet wall 3 feet high The earthwork on the outside face to have a slope of two to one, and that on the inside three to one This face is to be pitched

The area of the tank when standing at the level of the waste weir will be 175,000,000 square feet, or 6⅓ square miles This is $\frac{1}{22}$ of the area of rain-fall (141 square miles), and as the tank is calculated to hold 2,222,145,000 cubic feet of water, it will be filled by a rain-fall of 6½ inches on the whole drainage area * The maximum depth of water when the tank stands at the waste weir level will be 60 feet

The waste weir will be constructed on the northern end of the bund, and will consist of a channel 250 feet in width, which will be carried through the spur and will lead the waste water direct to a large nullah, by which it will rejoin the original stream, about a mile below the line of bund The depth of cutting on the ridge of spur will be 10 feet, at which level the material for the sill of the weir will be sufficiently hard to resist the wear of running water It is also proposed, however, in order to preserve the level of the weir crest, to lay down a flooring of masonry 25 feet wide, with an average depth of 1 5 feet across the waste weir.

The maximum discharge of the river Adeela, which is the stream on which the Sholapore lake is situated, is about 37,000 feet per second, according to the flood line shown by the villagers, and calculated by the usual formula, but there is reason to doubt whether it ever really reaches that amount, however, as this flood only lasts for a very few hours, it is not that one by which to decide the dimensions of the waste weir The discharge of that flood which continues for four or five days is about 11,000 cubic feet per second The velocity of discharge on the crest of

* Supposing the whole ran off, or by a rain fall of 0 inches, supposing two thirds ran off, the minimum fall at Sholapore is 13 inches —J G FIFE

the waste weir will be a little over 10 feet per second, but supposing it to be only 10 feet per second, with a width of 250 feet and depth of 5 feet—which is the maximum depth provided for—the discharge is 12,500 cubic feet per second, however, as the water will have been escaping all the while, the flood line will not rise to the height of 5 feet except under a very continuous rain-fall of above a week's duration at a time, and this is very improbable in these eastern districts

It would appear from the plan advisable to alter the position of the waste weir, and place it a little nearer the bund, but the nature of the ground does not admit of it At a less depth of cutting than 9 or 10 feet the material is not hard enough for the purpose, and by altering the situation, a natural advantage in the shape of the ground would be lost, and the waste water would have a greater tendency to spread over the land before reaching the nullah

The villages that will be submerged and destroyed by the construction of the lake are given below * Of these the first two belong to the British Government, the third is an Inam village under our control, and the last two belong to the Nizam The area of land belonging to these last two villages will be 415 acres

It was originally proposed that all the regulating sluices for discharging the water from this lake should consist of iron pipes laid on masonry, with screw cocks fitted on to their lower extremity, but as you considered this design hardly sufficient or safe for the sluice of the perennial canal, I have at your suggestion adopted the idea of the tower and tunnel originally proposed, I believe, by Sir Arthur Cotton, the method of working the small valves in the tower is shown on the tracing The sluices of the two high level canals will, however, consist of the former design

The joints of the piping, though generally made with iron filings or melted lead, should in this case consist of flanges bolted together with bolts and nuts, as no risk should be run The foundations of all the sluices will be on rock or hard moorum

It is proposed to run three lines of canals for distributing the water, that on the lowest level will be the perennial canal, the length being 28 miles Although the level of this canal at the head is 20 feet above the

* *British*—Hyperga, Danigaum and Waree *Inam in British Territory*—Ekroobh *Nizam*—Toradgaum, Pakler.

bed of the nullah or bottom of the lake, the quantity of water lost is only about 1-110th of the whole contents of the tank. This is not considered so valuable as the greater command of country which will be attained by the high level.

The next will be a four months' canal. It will start from the opposite side of the valley, cross the waste water channel, and terminate after a length of 18 miles. The third line will be on the same side of the valley as the perennial canal, but at a level 25 feet higher. It will also be a four-months' canal, and has only a length of 14 miles. The area of land commanded by these canals respectively is given below.*

The following calculations give the quantity of water required by the canals between the end of one monsoon and commencement of next eight months:—

912,384,000	cubic feet,	quantity run off by perennial canal in eight months.
435,456,000	ditto,	right bank canal in four months.
217,728,000	ditto,	left bank canal in four months.
750,000,000	ditto,	evaporation in eight months, 7 feet in depth.
20,000,000	ditto,	lost in bottom of tank.

As the tank will fill with less than the minimum rain-fall, the quantity of water withdrawn by the four-months' channel will be compensated for during the monsoon, and as the capacity of the tank is 2,222,145,000 there will be a considerable surplus, since the quantity required for the perennial canal evaporation, and loss at bottom of tank is only 1,682,380,000. The average velocity attained with the present distribution of fall in the canal is about 21 or 22 inches per second.

The works on each of the canals are as follows:—

Perennial Canal.—From the 1st to the 7th mile, the bottom width of canal to be 6 feet, the depth 3 feet, and side slopes one and a half to one, the fall being 1 foot per mile. In this length there are the following masonry works:—

One large aqueduct of five arches of 20 feet span.

* *Left bank, perennial canal.*—Discharge = 44 feet per second. Area 25 square miles or 16,000 acres.

Right bank, four months' canal.—Discharge = 42 feet per second. Area 21 square miles or 13,440 acres.

Left bank, four months' canal.—Discharge = 21 feet per second. Area 10 square miles or 6,400 acres.

One aqueduct of three arches of 20 feet, for passing the canal under a large railway arch
Four aqueducts of two arches of 10 feet span
One aqueduct of one arch of 10 feet span
Two escapes of three openings
Three escapes of two openings
One road bridge of 15 feet span, with 24 feet roadway

From the 7th mile to $8\frac{1}{2}$ miles, the bottom width will be $5\frac{1}{2}$ feet fall, &c, remaining the same as before The following will be the masonry works —

One aqueduct of two arches of 15 feet span
One aqueduct of two arches of 10 feet span
One escape of three openings
One bridge of 15 feet span, and 24 feet roadway

Between $8\frac{1}{2}$ miles and 10 miles, the width of channel to be 5 feet, the fall, &c., remaining the same. The masonry works here are only two escapes of two openings

From the 10th mile to 12th mile, the width will be $4\frac{1}{2}$ feet, and the fall 1 25 feet per mile The masonry works are as follows.—

One aqueduct with one arch of 15 feet span
Two aqueducts with two arches of 10 feet span
One escape of two openings

From 12th to 17th mile, the fall remains the same, but the width decreases to 4 feet. The works are as follows —

One aqueduct with two arches of 15 feet span
Three aqueducts with two arches of 10 feet span
One escape of three openings
One aqueduct with one arch of 10 feet span.
Four escapes of two openings

From the 17th to 19th mile, the width remains 4 feet, but the fall increases to 1 5 feet per mile, and the depth decreases from 3 feet to $2\frac{1}{2}$ feet The works consist of —

Three escapes of two openings.

Between the 19th and 20th miles, the width decreases to $3\frac{1}{2}$ feet The only masonry work is :—

One aqueduct with four arches of 20 feet span.

Between the 20th and 22nd miles, the fall will be 1 75 feet per mile, the width 3 feet, and the depth 2 feet The masonry works are.—

One aqueduct of two arches of 13 feet span
Two escapes of three openings
One road bridge, with arch of 15 feet span.

Between the 22nd and 24th miles, the fall remains the same, as well as the depth, but the width is only $2\frac{1}{2}$ feet The masonry works are —

One aqueduct of four arches of 15 feet span
One aqueduct of two arches of 15 feet span
One escape of two openings

From the 24th to the 28th mile, the fall per mile is 2 feet, the depth $1\frac{1}{2}$ feet, and the width of channel 2 feet The masonry works necessary here are —

Two aqueducts with one arch of 10 feet span
Two escapes with two openings
One escape with one opening

Right Bank, four-months' canal—From the 1st to 3rd mile, the fall is to be 1 foot per mile, the width 5 feet, and the depth 3 feet. The masonry works are —

One aqueduct with two arches of 15 feet span
Three escapes of two openings
One paved causeway for road

Between the 3rd and 6th miles, the width will be $4\frac{1}{2}$ feet, the depth and fall remaining the same. The masonry works are as follows —

One aqueduct with four arches of 15 feet span
One escape of three openings
One escape of two openings
One paved causeway for road

From the 6th to 9th mile, the fall and depth remaining the same, the width is reduced to 4 feet. The masonry works are —

One aqueduct with two arches of 15 feet span
One escape of three openings
Two escapes of two openings

Between the 9th and 12th miles, the fall is still to be 1 foot per mile, and depth 3 feet, but the width will be $3\frac{1}{2}$ feet The masonry works are —

One aqueduct with two arches of 15 feet span
Two escapes of three openings
Two escapes of two openings
One railway crossing, consisting of two culverts
One paved causeway for road

From the 12th to the 16th mile the fall will increase to $1\frac{1}{4}$ feet per mile, the width will be 3 feet, and the depth $2\frac{1}{2}$ feet The works are —

One escape of three openings
Three escapes of two openings

From the 16th to the 18th mile, the breadth to remain 3 feet, the fall will be 1·5 feet, and the depth 2 feet. There are no works at the tail of the canal.

Left Bank, four-months' canal.—The fall for the first 2 miles of this short canal, are respectively, 2 feet and $2\frac{1}{2}$ feet, the width is 3 feet, and depth 2 feet. The masonry works are simply —

One escape of two openings
One escape of one opening

For the 3rd and 4th mile, the fall is 3 feet per mile, and depth $1\frac{1}{2}$ feet, but the width for the 3rd mile is $2\frac{1}{2}$ feet, and that for the 4th mile, 2 feet. The only works required are —

One escape of two openings
One escape of one opening

Out of the whole area of land under command of the three canals, an allowance of one-fourth for waste would be very liberal indeed, as it is all of the very best description, and could be made into the finest garden land.

Extract of a Letter dated, 4th March, 1865, *from Colonel Fife, to the Revenue Commissioner, S.D.*

The site for this work was selected by myself two years ago, and at the same time I made the first rough or trial survey for the project. The result was sufficiently satisfactory to warrant a regular survey, and the preparation of complete plans and estimates, and these duties have been well performed by Mr. Campbell one of my Assistants, during the past year.

The stream, the Adeela, on which the lake will be situated, has a fall of about 7 feet per mile, and is the most advantageous I could find in the vicinity of Sholapore. The small streams and valleys of the Dekkan are, as a rule, too steep for storage works to pay, but the Adeela is an exception, and the result of the detailed survey and estimates is very satisfactory.

The sketch map attached to Mr. Campbell's report shows the site

for the lake. The dam across the valley is placed a little below the junction of the main stream with one of its principal tributaries, and the site is favourable from the contraction of the valley at the point, and the facility that is afforded for forming the waste weir, by cutting through a ridge which has boulders and rock close below the surface of the ground, and immediately beyond which there is a ravine, by means of which the waste water will return to the river without endangering the works in any way

The area of the lake when full up to the crest of the waste weir will be $6\frac{1}{3}$ square miles In length the lake will extend 8 miles up the valley, and there is very little doubt that such a vast sheet of water will materially reduce the temperature of the climate around it during the hot season, an advantage which will not be thought inconsiderable by those who know that miserable, hot, desert part of the country

The dam will be $1\frac{1}{2}$ miles in length, and 72 47 feet high in the centre of the valley It will be formed partly of earth, and partly of masonry, according to the nature of the ground Where a rock foundation is attainable, and soil for earthwork scarce, masonry, with a small quantity of earth to check leakage, is designed Where there is not a hard foundation, and earth is plentiful close at hand, the dam will be entirely of earth.

The channels themselves call for no particular remark, as the subject is well understood, but the arrangements for admitting water into them from the lake have been a source of much anxious consideration, and I took the opportunity of ascertaining Sir Arthur Cotton's opinion upon the question, as he is the great advocate for large storage works of this nature The common plan of using an iron pipe with a valve, which is practised in almost all town water supply works in England, is both an economical and a safe method when the quantity of water to be liberated is moderate, and the depth not very great, and this plan has been adopted for the small four months' canals, with the addition of an iron cage over the mouth of the pipe to prevent drift-wood or any large substance getting into the pipe But for the perennial canal, which starts at a point 41 73 feet below the surface of the lake, I have followed Sir Arthur Cotton's advice, which was to construct an inlet tower, with a number of small openings at different levels, and carry from its base through the dam a massive masonry culvert or tunnel,

much larger than is actually required for the free passage of the full supply of water The object of making the tunnel of such large capacity is, I should explain, to prevent any tendency to burst upwards, supposing any accident happened to the valves in the inlet tower, and a larger body of water than was wanted made its escape The masonry tunnel will of course bear any downward pressure upon it from the superincumbent earth, but an upward pressure if excessive, would burst it To make the regulation of the water doubly secure, I requested Mr Campbell to provide a separate chamber, attached to the inlet tower, for the regulation of valves at the tunnel entrance By means of these valves we shall be able to regulate the flow in such a manner as always to keep a good body of water in the inlet tower, for the water falling from above to fall upon, and we shall thus prevent injury to the masonry of the inlet tower, which would be subjected to a most tremendous action if the water, about 70 cubic feet per second, were permitted to fall the full height of the tower.

The quantity of water which will be furnished by the lake, and the area of cultivation and amount of revenue, are as follows. To distribute the water, however, the slopes of the canal will be increased agreeably to remarks on the details of the project attached to this letter —

Perennial Canal —The quantity of water available, after deducting from the whole capacity of the tank the loss by evaporation, &c, is 1,452,145,000 cubic feet for the perennial supply, which has to last from the end of one monsoon to the commencement of the following one This would furnish 70 cubic feet per second, which at the rate of 120 acres per foot, will give 8,400 acres

The area that may be cultivated on the right bank, four months' canal, with a discharge of 60 cubic feet per second, at 150 acres per foot, is 9,000 acres

The area that may be cultivated on the left bank, four-months' canal, with a discharge of 25 feet per second, at 150 acres per foot, is 3,750 acres

Assessing these areas at the rates given by the Superintendent of Revenue Survey, Major Francis, in his letter of the 27th April, 1864, to the Revenue Commissioner, the gross revenue will be as follows.—

	RS
8,400 acres of perennial crop, principally sugar-cane at rupees 8 per acre, ..	67,200
9,000 acres of four-months' crop on right bank canal, at rupees 4 per acre, ...	36,000
3,750 acres of four-months' crop on left bank canal, at rupees 4 per acre, ...	15,000
Total gross revenue, . .	1,18,200
Deducting from this for cost of establishment and maintenance at 3 per cent, on the outlay, rupees 7,76,275 for the project, ...	23,288
The net revenue will be,	94,912

or rupees 12 23 per cent, on the outlay

The percentage charge for maintenance is less than we generally allow to irrigation works, as much of the expenditure on this work is for the massive works in the dam, which will need but little repair

I believe the return on the outlay I have shown may be regarded as a very safe estimate. The people in Khandeish and else-where, when water lasts long enough for sugar-cane, most willingly pay even rupees 18 per acre, and it is not to be wondered at, as it is perfectly well known that the profit on an acre of sugar-cane is not less than rupees 150, and often much greater. There is also another point on which I know the calculations by Mr. Campbell are well on the safe side This is the loss by evaporation It is estimated at very nearly half as much as the quantity of water which will be drawn off by the perennial canal, on the assumption that the evaporation will amount to 7 feet perpendicular in the eight dry months But it is very evident that in such a vast sheet of water as that under consideration, which has an area of $6\frac{1}{4}$ square miles, the evaporation cannot be so large as in small tanks A great portion of the atmosphere over this lake will be brought to such a condition of humidity, that it will cease to absorb moisture with any rapidity. If the evaporation were reduced to one-half the estimated quantity, the perennial irrigation would be increased in area about one quarter, and this would at once add about rupees 17,000 to the net revenue, and bring the return up to rupees 1,11,912 or 14 42 per cent, on the outlay.

A great part of the land which will be submerged by the lake is almost waste, and what revenue is lost from the submergence of cultivated lands will, I think, easily be counterbalanced by a grazing tax,

which may fairly be imposed for the grazing along the margin of the lake, and on its bed, as the water recedes in the hot season. In that dry country the pasture will be invaluable.

Extract of a Memorandum on certain details of the project above by Colonel Fyfe, R.E.

The originally estimated rate for stone pitching was much too low, and has been increased in this office.

The chamber at the outer end of the large sluice tunnel must be altered in form during contruction. The contraction is much too great, as the water after being checked in velocity in the chamber, would make a fresh shoot at the contraction.

The inlet tower must be provided with a spiral staircase, of projecting stones outside, to admit of men getting on to the top from a boat when the lake is at a low level. The top of the tower must be provided with a parapet wall three feet high all round, and a wooden platform. The main valve chamber must be altered slightly in form. The curved wall must be still more curved, to bear the pressure of the water from the outside. This chamber will be dry, and is intended for the gear for working the valves, and also to enable a man to get down to the valves when necessary.

The parapet wall on the masonry dam should be raised to 4 feet, and its thickness should be increased to 2 feet.

The slopes of the canals must all be increased by about 1½ feet a mile, as in such small channels the theoretical velocity is never attained, except when the channels are first formed with their sides and bottom quite fair. The passage of a herd of cattle over a small channel makes the slopes uneven, and materially reduces the velocity of stream. A little excess of fall can be corrected at any time with ease, as there is plenty of hard ground, and places where even a rock foundation can be obtained for masonry falls. The increase of slope in the channels will make their theoretical discharge as follows:—

Perennial canal, 77·41 cubic feet per second, fall 2¼ feet per mile.

Right bank, four-months' channel, 70 cubic feet per second, fall 2½ feet per mile.

Left bank, four-months' channel, 81·77 cubic feet per second, fall 4 feet a mile.

In laying the material on to the earthern dam, stones and gravel must be reserved for the water slope, that a covering one foot in depth may be formed, on which the 2-feet pitching will be placed.

SHOLAPORE LAKE ESTIMATE.—RECAPITULATION

		RS.
	Main bund,	4,58,077
	Waste weir,	62,367
	PERENNIAL CANAL	
	Construction of canal,	41,721
	Regulating sluice,	19,746
23	Aqueducts of various spans,	56,300
1	Railway crossing,	2,456
3	Bridges,	3,432
23	Escapes,	2,830
10	Distributing sluices,	3,239
	RIGHT BANK, FOUR MONTHS' CANAL	
	Construction of Canal,	25,232
	Regulating sluice,	6,608
4	Aqueducts,	11,218
16	Escapes,	2,019
1	Railway crossing, of two culverts,	2,235
3	Paved causeways for roads,	287
8	Distributing sluices,	2,591
	LEFT BANK, FOUR MONTHS' CANAL	
	Construction of Canal,	2,876
	Regulating sluices,	2,078
4	Escapes,	893
	Total Rs,	7,05,705
	Contingencies, at Rs 5 per cent,	35,285
	Extra establishment, at Rs 5 per cent,	35,285
	Grand Total Rs,	7,76,275

Remarks by the Government of India.

In calculating the probable returns from the scheme, a sum of 5 per cent for establishment during construction appears to be far too small. It is considered that 15 per cent. will be a fair estimate, and this would bring the total cost of the undertaking to Rupees 10,09,374, reducing the net return to about 9 per cent., on the supposition that the work will be carried out for the amount of the estimate, and that the revenue will equal the anticipations of the projectors.

With regard to the return expected from the four months' canal, the rate of 150 acres of rice watered for every foot of discharge, although the amount will to some extent depend on the nature of the soil, appears somewhat high. It is thought that 90 acres per foot of discharge on these canals would be a nearer approximation to the probable results *

The rate allowed in the case of the perennial canal seems still to be high, considering that it is based on the supposition that all the land will either be irrigated for sugar-cane, or that there will be two crops on land within reach of the water Further, it is admitted that the acceptance of the rates by the people is doubtful, and will be a work of time

With regard to the details of the project, I am to notice the want of data on which to determine the amount of waterway to be allowed for the drainage across the canals, and to request that due attention may be given to this point before commencing work

The waste weir of the dam, as designed is 250 feet in length, its crest being 12 feet below the top of the dam With a depth of 5 feet of water over its crest, it will discharge 12,500 cubic feet of water per second.

Calculations based on the highest flood marks of the river which it is proposed to dam up, are said to give a maximum discharge of 37,000 cubic feet per second, but it is represented that such floods are of short duration and that the discharge in such floods, as last four or five days, is only about 11,000 cubic feet per second On these grounds, it is considered that the dimensions of the weir, as designed, are sufficient.

The point is one on which the opinions of the local officers are entitled to much consideration, but having regard to the large amount of water stored, and the immense destruction which any accident to the dam would cause, and looking also to the fact that a large additional length of weir may be provided with but little extra expense, His Excellency in Council is of opinion, that it is highly desirable to double the length of this weir, and desires that this be considered as one of the conditions under which sanction is accorded to the project.

* With reference to this remark I should explain, that the irrigation to be carried on by means of the four months' canals, is not entirely for rice, but for all the ordinary crops grown during the monsoon season. In the Sholapore District they principally consist of jowaree (the cholum of Madras) and bajerri crops, which require but little water, but which the people do irrigate when water is available. I believe that the effect of one cubic foot constant of discharge for 4 months is by no means over estimated at 150 acres.—J. G. FIFE

No. CLXXVIII

LAHORE CENTRAL JAIL.

BY LALLA KUNHYA LALL, *Executive Engineer*

THE Central jail at Lahore, of which, two drawings are annexed, consists of two circles, a hospital and godowns, placed in a quadrangular enclosure with a mud wall and ditch round it, measuring 1,614 feet in length, 84 feet in breadth, and 12 feet in height The wall is 8 feet thick at the bottom, and 2 feet at the top, and is built entirely of mud

The two circles, or rather octagons, have iron railings round them, with pucca masonry pillars at intervals of 12 to 13 feet each, to which the railings are firmly secured

The railings consist of straight bars of $1\frac{1}{4} \times 1\frac{1}{4}$ inch iron placed vertically at intervals of 4 inches, with horizontal bars of flat iron at top and bottom, the ends of which are well let into the pillars on either side, and the bottom part built up to 2 feet into solid pucka masonry. On the top of the railing, is a chevaux-de-frise, made of iron.

The railings round half the hospital compound, which is not adjoining the two circles, are made of wooden bars instead of iron.

The various buildings in the jail are detailed and described on the plan The outer wall, ditch, first circle, hospital, godowns, &c, and buildings at the gate were commenced in 1850, and completed in 1854 The second circle was built in 1862. The jail is capable of accommodating about 2,000 native and 10 European prisoners, and has cost in round numbers Rs 2,00,000.

The pillars of the iron railings, the gate pillars, and the bell tower,

the sun dial near the bell towers, are pucka and pucka pointed The are built entirely pucka, and pucka plastered The watch towers and European wards with their cook-houses, hospital, and the buildings at the gate, are kucha, pucka with coping of walls and water drips of roof pucka plastered The carpet shed, marked Q, and guard rooms, are kucha pucka and kutcha plastered. The wells are pucka, with chubootras and reservoirs pucka plastered. The rest of the buildings are kucha, of sun-dried large bricks, except insulated pillars, door jambs, and the flat arches over doors, which are kucha pucka, the whole of the masonry is kucha plastered inside and outside, and is kept in proper repairs by convict labor

Floors are all kucha, except those of the hospital, European wards, office of Superintendent, and Deputy Superintendent's quarters, which are terraced

Roofs of European wards, Superintendent's office and Deputy Superintendent's quarters, guard rooms, carpet shed, rooms over the gateway, are flat, on deodar beams; the watch towers have boarded roofs, and the rest of the buildings have pitched roofs of small tiles laid over flat tiles, resting on deodar battens and trusses solitary cells have flat roofs on ordinary bullees

Doors and windows of European wards, Superintendent's office, and Deputy Superintendent's quarters, are glazed, those of solitary cells, and watch towers, are battened and covered with sheet iron. Doors of wards for native prisoners are fitted with gratings of 1-inch square iron and provided with wooden shutters outside, the rest of the doors are common battened

The wards for Europeans and natives are well ventilated, and ventilation in solitary cells is provided by means of openings (faced with pucka pierced tiles) above and below the wall plate, *vide* details of cells given on plan

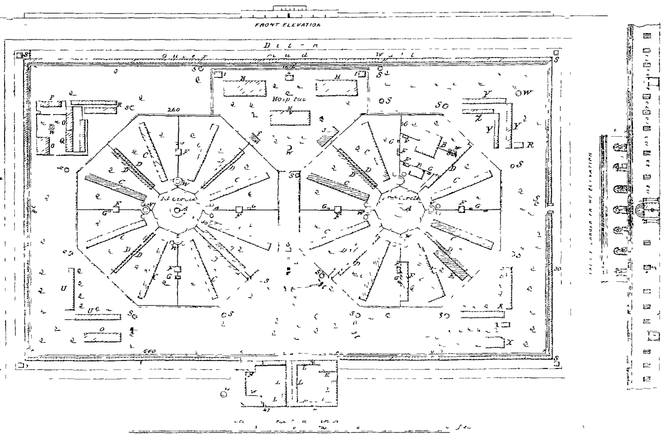
The main roads are metalled with broken bricks, and the whole of the inside is kept very neat and tidy by convict labor.

The inside of the jail is slightly raised above the level of the ground outside, and the drainage water of the whole area is discharged by means of open surface drains, into the ditch, which has a slope from all the four sides towards one corner, from which the whole of the drainage discharges itself into a drainage channel in the neighbourhood of the place.

K. L.

PLATE XI

PLAN OF LAHORE CENTRAL JAIL

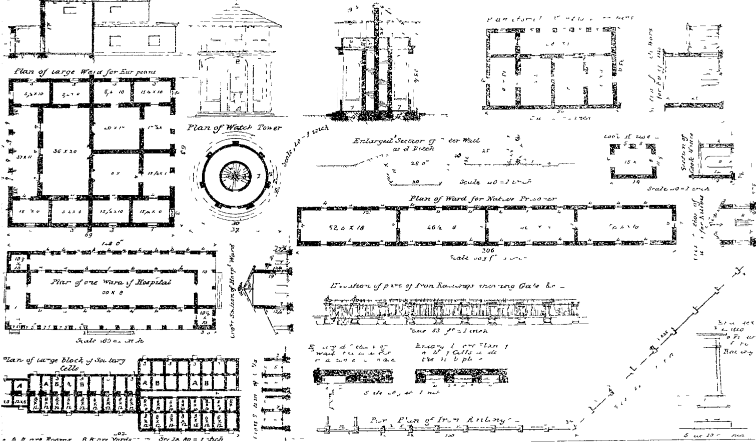


REFERENCES

A A Watch Towers
B B European Wards
C C Native do
D D Workshops
E E Solitary Cells
F F Cook houses
G G Privies
H H Hospital Wards
I I Dead Houses
J Native Doctor House
K Superintendents Office
L L Guard rooms
M Daroghas House
N Deputy Supdts do
O O Dyeing Sheds
P P
Q Juvenile Wards
R R Godowns
S S Sentry Boxes
T Bell Tower
U Godown for Raw Material
V Carpenters and Blacksmiths Workshops
W W Pucca Wells
X X Fetters Godown and Working Place
Y Y Paper Manufactory
Z Oil Sheds

PLATE XII

PLAN OF LAHORE CENTRAL JAIL



CLXXIX.

ROUTE SURVEY FROM NEPAL TO LHASA.

Narrative Report of a Route survey made by Pundit ——————, from Nepal to Lhasa and thence through the upper Valley of the Brahmaputra to its source Drawn up by* CAPTAIN T G MONTGOMERIE, R E, *of the G T Survey, in charge of the Trans-Himalayan Survey Parties.*

EXPLORATION beyond the frontiers of British India has, for many years, made but little comparative progress, and (as far as Europeans have been concerned) has been confined to points not many marches beyond the border

A European, even if disguised, attracts attention when travelling among Asiatics, and his presence, if detected, is now-a-days often apt to lead to outrage The difficulty of redressing such outrages, and various other causes, has, for the present, all but put a stop to exploration by Europeans On the other hand, Asiatics, the subjects of the British Government, are known to travel freely without molestation in countries far beyond the British frontier, they constantly pass to and fro between India and Central Asia, and also between India and Tibet, for trading and other purposes, without exciting any suspicion

In 1861 it was consequently proposed to take advantage of this facility possessed by Asiatics, and to employ them on explorations beyond the frontier. The Government of India approved of the project, and agreed to support it liberally

* The Pundit being still employed on exploration, his name is, for obvious reasons, omitted

With a view to carry out the above, Colonel Walker, the Superintendent G. T Survey, engaged two Pundits, British subjects, from one of the upper vallies of the Himalayas. These men were recommended by Major Smyth, of the Educational Department, as likely to have great facility in travelling through various parts of Tibet, their countrymen having always been granted by the Chinese authorities the privilege of travelling and trading in Nari-Khorsum, the upper basin of the Sutlej Such promising recruits having been secured, they were at once sent to the Head-Quarters of the G T. Survey, in order to be trained for Trans-Himalayan exploration

On Colonel Walker's departure for England, these Pundits were put under Captain Montgomerie, who completed their training They were found to be very intelligent, and rapidly learnt the use of the sextant, compass, &c, and before long recognized all the larger stars without any difficulty Their work, from actual practice, having been found to be satisfactory, Captain Montgomerie directed them to make a route-survey from the Mansarowar lake to Lhasa, along the great road that was known to exist between Gartokh and Lhasa From Lhasa, they were directed to return by a more northerly route to Mansarowar. The route to Lhasa was selected by Captain Montgomerie, because it was known, from native information, to be practicable as far as the road itself was concerned If explored, it was likely to define the whole course of the great river known to flow from near the Mansarowar lake to beyond Lhasa Hitherto the sole point on the upper course of this great river, the position of which was known with any certainty, was a point near Teshooloomboo, or Shigátze, as determined by Captain Turner in 1783. The position of Lhasa, the capital of Great Tibet, was, moreover only a matter of guess, the most probable determination having been derived from native information as to the marches between Turner's Teshooloomboo and Lhasa. In fact, the route from the Mansarowar lake to Lhasa, an estimated distance of 7 or 800 miles, was alone a capital field for exploration

An attempt was made by the Pundits to advance direct from Kumaon *viâ* Mansarowar, to Lhasa, but they did not find it practicable Whilst in Kumaon, they came across some British subjects, Bhotiyas, who had been robbed whilst trading in the Chinese territories, near Gartokh. These Bhotiyas thought that, if the matter was properly represented,

they might get redress from the Lhasa Government, and hearing that the Pundits were going to Lhasa, asked them to be their agents (vakeels), in order to recover what they could The Pundits consented, and one of them returned to Captain Montgomerie for fresh instructions The attempt by the Mansarowar lake having failed, it appeared to Captain Montgomerie that the best chance of reaching Lhasa would be through Nepal, as the Nepalese Government has always maintained relations of some kind with the Government of Lhasa Traders from Nepal, moreover, were known to visit Lhasa, and Lhasa traders to visit Nepal

Captain Montgomerie thought that the wish to recover money for the Bhotiyas of Kumaon would afford a plausible excuse for the Pundits' journey to Lhasa, an excuse the Nepalese would thoroughly understand, and he trusted the frequent intercourse with Lhasa would eventually afford the Pundits a good opportunity of travelling to that place in company with traders or others.

The Pundits were consequently ordered to go to Kathmandû, and from thence to try and make their way to the great road between the Mansarowar and Lhasa Their instrumental equipment consisted of 2 large sextants,* 2 box sextants, prismatic and pocket compasses, thermometers for observing temperature of air and of boiling water, pocket chronometer, and common watch, with apparatus, the latter reduced as much as possible

The Pundits started from Dehra, reached Moradabad on the 12th January, and Bareilly on the 23rd January, 1865 At Bareilly they took latitude observations, and commenced their route-survey They crossed the Nepalese frontier at Nepalgunj, Jung Bahadur's new town, and from thence went by the Cheesaghurri road to Kathmandû, reaching the latter place on the 7th March, 1865

After an attempt to reach Lhasa by the Kirong route which resulted in failure, they returned to Kathmandû on the 10th April and made fresh inquiries as to some more promising way of getting to Lhasa At last they heard of two opportunities, the first by accompanying the camp of a new agent (vakeel) that Jung Bahadur was about to send to Lhasa, and the second by accompanying a Bhot merchant In order to increase their chances of success, they decided that one should go

* Only one large sextant was taken to Lhasa

with the Nepal agent and the other with the merchant The vakeel at first agreed to take one of them with him, but ultimately refused

Failing with the vakeel, it was impossible for one of the Pundits, who happened to be well known to the Kirong governor, to go with the Bhot merchant, as he intended to take the Kirong route, he consequently decided to try a more circuitous route, by Muktináth, but in this he failed, owing, according to his own account, to loss of health, and the unsafe state of the roads, but, no doubt, in a great measure due to his own want of determination After a long journey through the upper parts of the Nepal territory, he returned to British territory The account of his proceedings is referred to separately. The other Pundit, at first, was not much more successful with the merchant than his brother had been with the vakeel The merchant, Dawa Nangal, promised to take the Pundit to Lhasa, and on the strength of that proceeded to borrow money from him. The merchant, however, put off starting from day to day, and eventually the Pundit had to start with one of the merchant's servants, the merchant himself promising to follow in a few days The Pundit assumed the dress of a Ladáki, and to complete his disguise, added a pig-tail to his head. This change was made, because he was afraid that the Kirong officials, who stopped him the first time, might recognise him again

Starting on the 3rd June with one servant and Dawa Nangal's man, he reached Shabrû on the 20th of June, having been delayed six days by a bad attack of fever At Shabrû he was kindly received by Dawa Nangal's family, but Dawa Nangal himself never made his appearance, and it became evident that he did not intend to keep his promise In his perplexity the Pundit appealed to Dawa Nangal's uncle, and told him how he had been treated The uncle, a man of some authority, said he sympathized with him, and gave him a pass to Kirong and a letter to Dawa Nangal's brother, who had just returned to Kirong from Lhasa In the letter he mentioned that the Pundit's claim against Dawa Nangal was just, and, in consequence, requested him to arrange for the Pundit's journey to Lhasa, and, if necessary, to stand security for him.

Starting on the 6th July with one of the uncle's servants, the Pundit managed to make his way into Kirong Here he found Dawa Nangal's brother, by name Chúng Chú. Chúng Chú, on hearing the state of

the case, promised to assist the Pundit on to Lhasa, but refused to pay his brother's debt Chúng Chú proved himself a better man than his brother, for, though permission to travel by the direct route was refused, he ultimately succeeded in getting the Pundit permission to travel onwards, by this means he reached Tadúm monastery, a well known halting place on the great road between Lhasa and Gartokh Starting on the 13th August from Kirong, he reached Lue on the 23rd From Kathmandû up to this point vegetation and jungle had been abundant, but, beyond, the mountains were throughout bare, and all but barren

On the 24th August the Pundit joined a large trading party, travelling *viâ* Tadúm to Mansarowar, and was allowed to accompanying them On the 30th he reached Talla Labrong, and there first caught sight of the great river* that flows towards Lhasa His first acquaintance with this river was calculated to inspire him with respect for it, as three men were drowned in front of him, by the swamping of a ferry boat Alarmed by this occurrence, the party marched a short distance farther up the river to a better ferry, by which they crossed in safety to the Tadúm monastery on the 6th of September At Tadum the Pundit feigned sickness, as a reason for not going on to Mansarowar, and he was accordingly left behind Continuing to feign illness, he last found an admirable opportunity of going to Lhasa, viz, by accompanying a Ladák merchant in the employ of the Kashmir Maharaja, who was that year going to Lhasa, and was to pass through Tadum On the 2nd of October the merchant's head man, Chiring Nirpal, arrived, and on hearing the Pundit's story, at once consented to take him on to Lhasa Starting on the next morning with the Ladáki camp, he marched eastwards along the great road, reaching the town of Sarkajong on the 8th October. So far everything had gone smoothly, but here the inquiries, made by the authorities rather alarmed the Pundit, and as his funds, owing to the great delays, had begun to run short, the two combined made him very uneasy However, he manfully resolved to continue his journey He became a great favorite with Chiring Nirpal and the whole of the Ladáki camp On the 19th October they reached Ralang From Tadúm to this point no cultivation was seen, but here there was a little, and a few willow trees, and onwards to Lhasa cultivation was met with nearly every day

* The Brahmaputra.

On the 22nd October the party reached the town of Janglache, with a fort and fine monastery on the Nárichú*, the great river first met with near Talla Labrong From this point people and goods are frequently transported by boats to Shigátze, 5 days march (85 miles) lower down the river. Most of the Pundit's companions went by boat, but he having to survey, count paces, &c , went by land On the 29th October they reached Digarcha, or Shigátze, a large town on the Penanangchú river near its junction with the great Nárichú river At Shigátze, Chirung Nirpal had to wait for his master, the head merchant, called Lopchak The Pundit consequently remained in that town till the 22nd of December The Lopchak, who arrived on the 16th November, saw no objection to the Pundit continuing with the party, and, moreover promised to assist him at Lhasa. Whilst at Shigátze the Pundit and his companions remained in a large sort of caravanserai called Kunkhang The only incident during their long stay there was a visit that he and the Ladákis paid to the great Tashilumbo monastery. This monastery lies about half a mile south-west of the city, and is the same as that visited, and fully described, by Turner The Pundit would rather not have paid the Láma a visit, but he thought it imprudent to refuse, and therefore joined the Ladákis, who were going to pay their respects to him. The Pundit confesses that, though personally a follower of Brahma, the proposed visit rather frightened him, as, according to the religion of his ancestors, who were Budhists, the Lama ought to know the secrets of all hearts However, putting a bold face on the matter, he went and was much relieved to find that the Lama, a boy of 11, only asked him three simple questions, and was, according to the Pundit, nothing more than an ordinary child and did not evince any extra intelligence At Shigátze the Pundit took to teaching Nepalese shopkeepers the Hindoo method of calculation, and thereby earned a few rupees

The great road, which had hitherto been more or less close to the great Nárichú river, from Shigátze goes considerably south of that river On the 25th December they reached the large town of Gyange, on the Penanangchú river, which was then frozen hard enough to bear men. Crossing the lofty Kharola mountains, they arrived on the 31st December at Nang-ganche jong, a village on the Yamdokcho lake, with the

* The Brahmaputra river

usual fort on a small hill For two days the Pundit coasted along the Great Yamdokcho lake.* On the second day he nearly fell a prey to a band of robbers, but, being on horseback,† he managed to escape, and on the 2nd January reached Demálang, a village at the northern angle of the lake From Demálang the lake was seen to stretch some 20 miles to the south-east The Pundit estimated the circumference of the lake to be 45 miles, but, as far he saw, it was only 2 to 3 miles in width He was informed that the lake encircled a large island, which rises into low rounded hills 2 or 3,000 feet above the surface of the lake These hills were covered with grass up to the top Between the hills and the margin of the lake several villages and a white monastery were visible on the island The villagers keep up their communication with the mainland by means of boats The Pundit was told that the lake had no outlet, but as he says its water was perfectly fresh, that is probably a mistake, if so, the Pundit thinks the outlet may be on the eastern side, where the mountains appeared to be not quite so high as those on the other sides. The evidence as to the lake encircling a very large island is unanimous Almost all former maps, whether derived from the Chinese maps made by the Lamas, or from native information collected in Hindustan, agree in giving the island a very large area, as compared with the lake in which it stands. This is however a very curious topographical feature, and as no similar case is known to exist elsewhere, it might perhaps be rash to take it for granted, until some reliable person has actually made the circuit of the lake. Meantime the Pundit's survey goes a considerable way to confirm the received theory. The lake, from the Pundit's observations, appears to be about 13,500 feet above the sea, it contains quantities of fish The water was very clear, and said to be very deep.

The island in the centre must rise to 16,000 feet above the sea, an altitude at which coarse grass is found in most parts of Tibet

From the basin of the Yamdokcho lake the party crossed over the Khambala mountains by a high pass, reaching the great Nárichú (the Brahmaputra) at Khambabarche, from thence they descended the river in boats to Chusul village Near Chusul they again left the great

* The margin of the lake was frozen

† With reference to this, the Pundit on being questioned said that the paces of this portion, and of one or two other parts, were counted on his return journey.

river, and ascending its tributary the Kichu Sangpo or Lhasa river, in a north-easterly direction reached Lhasa on the 10th of January, 1866

The Pundit took up his abode in a sort of caravanserai with a very long name, belonging to the Tashilumbo monastery, he hired two rooms that he thought well suited for taking observations of stars, &c, without being noticed Here he remained till the 21st of April, 1866 On one occasion he paid a visit to the Goldan monastery, two marches up the great road to China, which runs from Lhasa in a north-easterly direction He also attempted to go down the Brahmaputra, but was told that it was impossible without a well armed party of a dozen at least His funds being low, he was obliged to give up the idea, and indeed, judging from all accounts, doubted if he could have done it with funds The Pundit's account of the city of Lhasa agrees, in the main, with what has been written in Messrs Huc and Gabet's book as to that extraordinary capital, which the Pundit found to be about 11,400 feet above the sea He particularly dwells upon the great number, size and magnificence of the various monasteries, and the vast number of monks, &c, serving in them.

He had an interview with the Grand Lama, whom he describes as a fair and handsome boy of 13 years of age The Lama was seated on a throne 6 feet high, and on a lower throne to his right was seated his chief minister, the Gyalbo* or Potolah raja, as he is called by the Newar people. The Gyalbo is evidently the actual ruler of Lhasa, under the Chinese ambán or resident, the Grand Lama being a puppet in the hands of the Gyalbos

It is curious that the few times these great Lamas have been seen by reliable people, they have been always found to be small boys, or fair, effeminate-looking young men Moorcroft remarks on the emasculated appearance given to them in all the pictures of them that he saw during his journey to Gartokh, and the same may be remarked as to the pictures of Lamas in the monasteries of Ladak. M Huc says that the Delai Lama at Lhasa, during their visit in 1846, was nine years of age, and had been grand Lama for only six years, so that he must have transmigrated once, at any rate, between that time and the Pundit's visit in 1866, possibly oftener, as M Huc says that, during the time one Nomekhan or Gyalbo was in office, "three successive Delai La-

* Or Gyalpo

mas had died very soon after reaching the age of majority." Turner found the Grand Tashilumbo Lama quite a child in 1783 From the above it would appear that the poor Lamas are made to go through their transmigrations very rapidly, the intervals being probably in inverse proportion to the amount of trouble they give to the Gyalbo, If the Pundit is right in saying that the Lamas are only allowed to transmigrate thirteen times, and the present Delai Lama is in his thirteenth body, some changes may be expected before very long in the Lhasa Government The Pundit gives a very curious account of the festival observed at Lhasa on and after their new year's day

Having been so long away, the Pundit's funds had arrived at a very low ebb, and he was obliged to make his livelihood by teaching Nepalese merchants the Hindoo method of accounts By this means he got a little more money, but the merchants, not being quite so liberal as those of Shigátze, chiefly remunerated him by small presents of butter and food, on which he managed to subsist. During his stay in Lhasa the Pundit seems to have been unmolested, and his account of himself was only once called in question On that occasion two Mahomedans of Kashmiri descent managed to penetrate his disguise, and made him confess his secret However they kept it faithfully, and assisted the poor Pundit with a small loan, on the security of his watch. On another occasion the Pundit was surprised to see the Kirong governor in the streets of Lhasa This was the same official that had made so much difficulty about letting him pass Kirong, and as the Pundit had (through Chúng Chú) agreed to forfeit his life if, after passing Kirong, he went to Lhasa, his alarm may easily be imagined Just about the same time the Pundit saw the summary way in which treachery was dealt with in Lhasa A Chinaman, who had raised a quarrel between two monasteries, was taken out and beheaded without the slightest compunction All these things combined alarmed the Pundit so much that he changed his residence, and from that time seldom appeared in public

Early in April the Pundit heard that his Ladáki friends were about to return to Ladák with the tea, &c, that they had purchased He forthwith waited on the Lopchak, and was, much to his delight, not only allowed to return with him, but was told that he would be well cared for, and his expenses paid *en route*, and that they need not be

repaid till he reached Mansarowar The Pundit, in fact, was a favourite with all who came in contact with him

On the 21st April he left Lhasa with the Ladáki party, and marching back by the great road as before, reached Tadúm monastery on the 1st of June

From Tadúm he followed the great road to Mansarowar, passing over a very elevated tract of country, from 14 to 16,000 feet above the sea, inhabited solely by nomadic people, who possess large flocks and herds of sheep, goats and yaks On the road his servant fell ill, but his Ladáki companions assisted him in his work, and he was able to carry it on. Crossing the Mariam-La mountains, the watershed between the Brahmaputra and the Sutlej, he reached Darchan, between the Mansarowar and the Rakas Tál, on the 17th of June Here he met a trader from British territory who knew him, and at once enabled him to pay all his debts, except the loan on his watch, which was in the hands of one of the Ladákis He asked his friends to leave the watch at Gartokh till he redeemed it

At Darchan the Pundit and his Ladáki companions parted with mutual regret, the Ladákis going north towards Gartokh, and the Pundit marching towards the nearest pass to the British territory, accompanied by two sons of the man who had paid his debts

The Pundit's servant, a faithful man from Záskar in Ladák, who had stuck to him throughout the journey, being ill, remained behind. He answered as a sort of security for the Pundit, who promised to send for him, and at the same time to pay all the money that had been advanced Leaving Darchan on the 20th June, the Pundit reached Thájung on the 23rd, and here he was much astonished to find even the low hills covered with snow in a way he had never seen before The fact being that he was approaching the outer Himalayan chain, and the ground he was on (though lower than much of the country he had crossed earlier in the season) was close enough to the outer range to get the full benefit of the moisture from the Hindustan side The snow rendered the route he meant to take impracticable, and he had to make a great detour. After an adventure with the Bhotiyas, from whom he escaped with difficulty, he finally crossed the Himalayan range on the 26th June, and thence descended into British territory after an absence of 18 months As soon after his arrival as possible, the Pundit sent back

two men to Darchan, with money to pay his dobtans, and directions to bring back his servant. This was done, and the servant arrived all safe, and in good health.

The Pundit met his brother, who failing to make his way to Lhasa had returned by a lower road through the Nepalese territory. This brother had been told to penetrate into Tibet, and, if possible, to assist the Pundit. The snow had however prevented him from starting. He was now, at the Pundit's request, sent to Gartokh to redeem the watch, and to carry on a route survey to that place. The Pundit handed over his sextant, and told him to connect his route with the point where the Bhotiyas had made the Pundit leave off. The brother succeeded in reaching Gartokh, redeemed the watch, and after making a route-survey from the British territories to Gartokh and back, he rejoined the Pundit, and they both reached the Head-Quarters of the Survey on the 27th of October, 1866.

During the regular survey of Ladák, Captain Montgomerie had noticed that the Tibetans always made use of the rosary and prayer-wheel,* he consequently recommended the Pundit to carry both with him, partly because the character of a Budhist was the most appropriate to assume in Tibet, but, still more, because it was thought that these ritualistic instruments would (with a little adaptation) form very useful adjuncts in carrying on the route-survey.

It was necessary that the Pundit should be able to take his compass bearings unobserved, and also that, when counting his paces, he should not be interrupted by having to answer questions. The Pundit found the best way of effecting those objects was to march separately with his servant either behind or in front of the rest of the camp. It was of course not always possible to effect this, nor could strangers be altogether avoided. Whenever people did come up to the Pundit, the sight of his prayer-wheel was generally sufficient to prevent them from addressing him. When he saw any one approaching, he at once began to whirl his prayer-wheel round, and as all good Budhists whilst doing that, are supposed to be absorbed in religious contemplation, he was very seldom interrupted.

The prayer-wheel consists of a hollow cylindrical copper box, which

* The mani chuskor, or prayer-wheel

revolves round a spindle, one end of which forms the handle. The cylinder is turned by means of a piece of copper attached by a string. A slight twist of the hand makes the cylinder revolve, and each revolution represents one repetition of the prayer, which is written on a scroll kept inside the cylinder.* The prayer-wheels are of all sizes, from that of a large barrel downwards, but those carried in the hand are generally 4 or 6 inches in height by about 3 inches in diameter, with a handle projecting about 4 inches below the bottom of the cylinder. The one used by the Pundit was an ordinary hand one, but instead of carrying a paper scroll with the usual Budhist prayer, "Om mani padmi hom," the cylinder had inside it long slips of paper, for the purpose of recording the bearings and number of paces, &c. The top of the cylinder was made loose enough to allow the paper to be taken out when required.

The rosary, which ought to have 108 beads, was made of 100 beads, every tenth bead being much larger than the others. The small beads were made of a red composition to imitate coral, the large ones of the dark corrugated seed of the udras. The rosary was carried in the left sleeve; at every hundredth pace a bead was dropped, and each large bead dropped, consequently, represented 1,000 paces. With his prayer-wheel † and rosary the Pundit always managed in one way or another to take his bearings and to count his paces.

The latitude observations were a greater difficulty than the route-survey. The Pundit required to observe unseen by any one except his servant; however with his assistance, and by means of various pretences, the Pundit did manage to observe at thirty-one different places. His observations for latitude were all taken with a large sextant, by Elliot, of 6 inch radius, reading to ten seconds. The Pundit was supplied with a dark glass artifical horizon, but Captain Montgomerie finding that it was far from satisfactory, ordered the Pundit not to use it, unless he found it impossible to use quicksilver. A shallow wooden trough with a spout was made for the quicksilver, but as anything in the shape of a glass cover could not be carried, the Pundit was directed to protect his quicksilver from the wind as he best could,

* This prayer is sometimes engraved on the exterior of the wheel.

† The Pundit found this prayer wheel free of all examination by Custom House or other officials. In order to take full advantage of this immunity, several copper prayer wheels have been made up in the G. T. S. Workshop, fitted for compasses, &c.; these will be described hereafter.

by sinking it in the ground, &c. The Pundit had invested in a wooden bowl,* such as is carried at the waist by all Bhotiyas. This bowl is used by the Bhotiyas for drinking purposes, in it they put their water, tea, broth, and spirits, and in it they make their sturabout with dry flour and water, when they see no chance of getting anything better. The Pundit, in addition, found this bowl answer capitally for his quicksilver, as its deep sides prevented the wind from acting readily on the surface. Quicksilver is a difficult thing to carry, but the Pundit managed to carry his safely nearly all the way to Lhasa, by putting some into a cocoanut, and by carrying a reserve in cowrie shells closed with wax. At Piáhte-jong however the whole of his quicksilver escaped by some accident, fortunately he was not far from Lhasa, where he was able to purchase more. The whole of his altitudes were taken with the quicksilver.

Reading the sextant at night without exciting remark was by no means easy. At first a common bull's-eye lantern answered capitally, but it was seen and admired by some of the curious officials at the Tadúm monastery, and the Pundit, who said he had brought it for sale was forced to part with it, in order to avoid suspicion. From Tadúm onwards a common oil wick was the only thing to be got. The wind often prevented the use of it, and, as it was difficult to hide, the Pundit was at some of the smaller places obliged to take his night observation, and then put his instrument carefully by, and not read it till the next morning, but at most places, including all the more important ones, he was able to read his instrument immediately after taking his observations.

The results of the expedition delivered at the Head-Quarters consists of—

1st.—A great number of meridian altitudes of the sun and stars, taken for latitude at thirty-one different points, including a number of observations at Lhasa, Tashilumbo, and other important places.

2nd.—An elaborate route survey, extending over 1,200 miles defining the road from Kathmandú to Tadúm, and the whole of the Great Tibetan road from Lhasa to Gartokh, fixing generally the whole course of

* The Tibetans are very curious as to these drinking bowls or cups, they are made by hollowing out a piece of hard wood, those made from knots of trees being more especially valued. A good bowl is often bound with silver. The wood from which they are made does not grow in Tibet, and the cups consequently sell for large amounts.

the great Brahmaputra river from its source near Mansorawar to the point where it is joined by the stream on which Lhasa stands

3rd.—Observations of the temperature of the air and boiling water, by which the height of thirty-three points have been determined, also a still greater number of observations of temperature, taken at Shigátze, Lhasa, &c, giving some idea of the climate of those places

4th.—Notes as to what was seen, and as to the information gathered during the expedition

(To be Continued)

FUTURE IRRIGATION WORKS.

THE following extract from a speech of His Excellency the Viceroy, delivered in Council on the 31st March last, will show the number and nature of the various great Irrigation Works in hand, or about to be undertaken, by the Government of India:—

It was from the very first perfectly well known by all the officers of the Government concerned with the administration of the Public Works Department, that any very rapid prosecution of new irrigation works was not to be expected at first starting India was the only school for engineers who had the special knowledge which was requisite for making projects for such works, and they must therefore wholly rely upon their own resources in respect to the first designs At the same time, from the comparatively small number of engineers who had been employed on irrigation works in past years, and from the special qualifications needed for preparing new projects, and from the obligation to maintain all existing works in proper efficiency, there had been an absolute limit put to the number of officers who could be set to work on the preparation of new designs But considering all these things, the progress made since the Home Government finally gave their assent to the proposals of the Government of India, relative to the extension of irrigation, had been very satisfactory

To show generally what had been done in the way of pushing on projects during the last year, the operations of each province would be briefly mentioned

Beginning with the Punjab, they had the new project for a Canal

from the Sutlej, roughly estimated to cost about two millions, which would immediately receive sanction to admit of the exact line being marked out on the ground, and the detailed designs and estimates of the works prepared It might be hoped that work would actually be begun next season

Next the remodelling of the Baree Doab Canal, with a view to increasing the supply of water from the Beas river, was under consideration Also a large project for improving the Western Jumna canal, and for extending it into the arid districts near Sirsá

Surveys had also been put in hand for projects for Canals to be derived from the Sutlej, during the monsoon months, for the country between Firozpoor and Múltán, and like surveys were also going on for extending the Canals on the right bank of the Indus

There had been some difficulty in finding qualified officers for all these surveys, but they were believed to be going on satisfactorily

In the North-West Provinces, a new project for a Canal from the Jumna, to leave it below Delhi and to irrigate the Agra and Muttra districts, at a cost of about half a million, had been sanctioned in the rough, and was already in great part marked out The remodelling of the Ganges Ganal, and the arrangements needed for making it a complete line of navigation throughout its length, were in progress, and some parts of the designs had already been received When these and other contemplated navigation-lines were carried out, there would be continuous water communication from Lahore to Delhi, Agra, the Doab, and on into Oudh

Plans were under consideration for carrying out extensive works in Rohilkhund on the north of the Ganges, which would combine irrigation and drainage

Engineers were also at work in Bundelkhund, preparing projects for utilizing the water of the three chief rivers which flowed through that province. In connexion with these operations it would be seen whether a further supply of water could be secured from the lower part of the Jumna to be led to Allahabad.

In the province of Oudh, surveys were also in progress for a Canal to be taken from the Saidá; this would be a first class work, not

smaller than the Ganges Canal, and might probably cost two millions or more.

In Bengal on the North, the engineers were at work in Tirhoot, with a view of utilizing the water of the Gaudak river. Also surveys had been begun in Nuddea, which might lead to the formation of a Canal, often talked of, to be led from the Ganges near Rajmahal, perhaps as far as Calcutta. A project was well advanced for a canal from the Damúdáh to serve as a navigation and irrigation work, and communicating between the coal district of Ráníganj and the Hooghly. Other designs on some of the other neighbouring rivers of this part of Bengal were also in hand.

The Canal from the Soane, which was to have been carried out by the East India Irrigation Company, would probably be handed over to the Government for execution, and arrangements would be made for beginning it as soon as the negotiations with the Company would permit. The works of the same Company in Orissa continued to progress.

In the Central Provinces, an officer had been obtained from Madras for the special prosecution of irrigation works, and two promising projects were well forward, and might probably be in a fit state for submission to the Government of India for sanction in a month or two.

In Madras, the attention of the engineers had been specially directed to the preparation of projects for the completion of the great works connected with the anicuts on the Godaveri and Kistna. Portions of these had already received sanction, and the rest were expected soon to be sent up. Two very large tank works were in course of execution near Madras itself. A large project had lately been sanctioned for the extension of the irrigation from the Pennar river in the Nellore district.

A survey had also been carried out for a Canal, to turn the water of a river rising in the higher ranges of the Travancore mountains, into the plain of Madura. There were considerable difficulties to be encountered in the realization of this scheme, but it was hoped that they might be satisfactorily met.

Other projects of value were under preparation in the Madras Presidency, and important improvements in the Cauvery works were also contemplated

In the Bombay Presidency, beginning with Sind, a very large scheme for a Canal from the Indus at Roree, to irrigate the Hyderabad collectorate, was under consideration Other projects were in hand for improvements of other existing canals in that province

In Guzarát, a project for a Canal from the Taptí had just been sent up for sanction by the Government of India, and another project was believed to be in preparation for another valuable work

In Khandeish, one work of importance was already in operation, and the engineers were employed in preparing for its extension

In the Deccan there were numerous projects in various stages of progress, and several new schemes of magnitude almost ready for final submission to Government

Lastly, in Mysore, additional vigour had been given to the progress of irrigation works, and it had been proposed to apply a large sum from the accumulated surplus revenues, in excess of the annual grants from current income, to the prosecution of these works

To strengthen the hands of the Government in respect to engineers for employment on the new works which would soon begin to be ready for execution, the Secretary of State had, at the urgent request of the Government of India, sent out to this country thirty civil engineers of experience, the greater part of whom had already arrived, and would be immediately distributed among the Local Governments, where their services were likely to be most needed Increased numbers of young officers would also be appointed by the Secretary of State in the course of the coming year, so that it was hoped that no further difficulty of importance would be met with from this quarter.

No CLXXX

THE FRERE HALL—KURRACHEE.

Memo by LIEUT G MEREWETHER, R E

ON Sir Bartle Frere leaving Sind, in October 1859, to take his seat as a Member of the Governor General's Council, steps were immediately taken to show in a substantial manner the esteem in which the people of Sind held him, and their gratitude to him for his able and successful administration of the affairs of the Province during a lengthened rule of nearly nine years

With this view sums were subscribed by private individuals, within a few months of his leaving Sind, amounting to about Rs 20,000, and to this the Kurrachee Municipality added Rs 5000

In the first place, a Silver Vase costing Rs 2,646, with a suitable inscription, was purchased for presentation to Sir Bartle Frere, but the Secretary of State deciding against such a presentation during his continuance in Government service, the piece of plate was placed in the care of trustees, pending the owner's retirement from the service Several suggestions were made as to the manner in which the remaining money might be most advantageously used It was proposed to found scholarships in the Government schools of the three Collectorate towns of Sind, to enlarge the General and Native Libraries at Kurrachee, and to obtain a Portrait of Sir Bartle Frere, but all of these were abandoned in favor of the erection of a building much wanted in Kurrachee, for Public Meetings, Lectures, Balls, Concerts, &c. Arrangements were being made for the erection of such a building with the funds at the disposal of the Frere

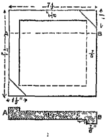
Testimonial Committee, when the Municipal Commissioners offered an extra grant of Rs 50,000, on condition that the building should, on completion, become the property of the Municipality, that body agreeing that it should always be available for public purposes, and should be called the *Frere* Hall This was agreed to, and new designs, suitable to the increased sum at the disposal of the Committee, were invited

Twelve were received, ten from India and two from England, and of these, that of Captain (now Lieut -Col) H St C Wilkins, R E (Bombay), was unanimously adopted, it being considered in every way the best adapted for the purpose.

The accompanying Photograph and plans will explain the style of building

It stands nearly in the middle of a fine open space which has been reserved for it, and situated in the highest and best part of Kurrachee The mass of the building is composed of limestone, obtained within four miles of Kurrachee The columns of the verandahs of the upper storey are of white oolitic limestone obtained from Bolari, about 80 miles from Kurrachee, on the Sind Railway Company's Line The voussoirs of the arches in the lower storey are alternately of the Bolari oolite and of a dark gray sandstone obtained from Joongshaie, 53 miles from Kurrachee on the Sind Railway

Those of the upper storey have a dark red sandstone, instead of the gray used in the lower storey For the greater part of the roof, tiles, as shown in the figure, are used

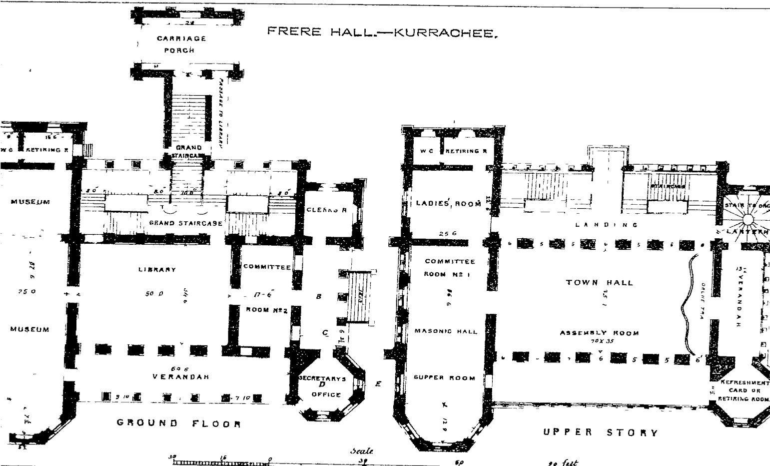


For that of the north-east verandah, which is very flat, galvanized corrugated iron has been adopted The spirelet and octagonal tower are covered with Muntz's metal The floors of the lower storey are paved with stone throughout Encaustic tiles for that of the smoking room in the octagonal tower, are being sent out by Messrs Minton & Co

The ceiling of the large hall is coved and of plaster. All others are of the best teak, and no other wood is used throughout the building The expenditure up to the present time has amounted to about Rs 1,80,000, the extra amount required having been provided by the Municipal Com-

FRERE HALL.—KURRACHEE.

FRERE HALL.—KURRACHEE.



mission This includes furnishing the building, laying out the grounds to some extent, forming approaches and drives, building culverts, and sinking a boring within a few yards of the Hall to a depth of 130 feet below the surface

This boring operation will be continued, and it is hoped that it will lead to a supply of water being obtained, which will greatly facilitate the growth of trees and shrubs in the grounds, the want of foliage being now the great drawback to this part of Kurrachee

As funds become available, the grounds will be enclosed by a suitable dwarf stone wall carrying an iron railing; cast-iron entrance gates will be provided, gate keeper's lodges built, the walls and ceilings of the large hall will be painted, and other works will be carried out, the whole of which it is estimated will cost about Rs 50,000

The building has been erected by an English contractor under the direction of a Building Committee, composed of gentlemen selected from the General Committee in whose hands the funds for the testimonial were placed

Arrangements are being made for making the whole of the lower storey available for the reception of the General Library and Museum, leaving the upper storey for Municipal Meetings, Lecture Rooms, &c., &c

The building was begun in August 1863, and was opened to the public on the 10th October, 1865, the 6th anniversary of the day on which it was decided to carry out some such work as a lasting memorial of Sir Bartle Frere's rule in Sind

A Durbar was held in it by him, as Governor of Bombay, in February 1867

G M.

No CLXXXI

NOTES ON IRRIGATION IN THE BOMBAY PRESIDENCY

By H Victor, *Sub-Engineer*, P. W. D

Land Tenure Assessment, and System of Division—To the Officer engaged on Irrigation projects, some slight acquaintance with the Revenue Survey* and Assessment system of this Presidency is necessary, so as to form an idea of the return on a work

Each village has a defined boundary, and the ground lying within it is divided into fields, these divisions being surveyed, marked out and numbered, are shown on a plan with which each village is furnished, the different classes of soil, as *jeraet*, or dry crop land, *baghaet*, or garden land, and waste, with the particular description of tenure, as *inam*, *merass*, *gutkool*, being distinguished by tints A register accompanies each map, in which all particulars of soil, tenants, and amount of assessment are recorded

The fixed field assessment is for a term of 30 years, administered by annual leases

The size of fields is limited principally to meet the means of the ryots, and is determined by the extent of the particular description of soil which could be cultivated with the assistance of one pair of bullocks This extent is governed by various circumstances, but is put down as follows —

20	Acres	of light dry crop soil
15	„	of medium „
12	„	of heavy „
6	„	of garden land
4	„	of rice land

* See No CX of these Papers

The different kinds of cultivation, as dry crop, garden, rice, &c., are made as distinct as practicable.

The divisions of the fields in dry crop lands are distinguished by a strip of uncultivated land, by stones let in along the boundaries, or by mounds of earth raised at the corners and bends, where boundaries meet, the direction in which these mounds lie points out the division lines.

The measurements of the fields are taken with a *goonta* chain of 33 feet, and when reduced to plotting are shown on a scale of from 20 to 40 chains to an inch. A rod of 8 feet 3 inches is also used.

The classification of land is the determination of the value of the fields into which it is divided. The circumstances affecting this value, when the climate is the same, are the position of the fields with respect to the village, the facilities for agricultural operations, the character of the soil, and, in the case of garden or rice land, the opportunities presented for irrigation.

The varieties of soil are placed under nine classes, each of a relative value in annas or 1-16th of a rupee, and the particular order of soil placed under three heads, as shown in the following table:—

Class	Relative value of class in annas or 16ths of a rupee	Soils of the		
		1st Order	2nd Order	3rd Order
		Of a fine uniform texture, varying in color from deep black to dark brown	Of a coarser nature than the preceding, and lighter also in color, generally red	Of coarse gravelly, or loose friable texture, and color varying from light brown to gray
		Depth in Cubits	Depth in Cubits	Depth in Cubits
1	16	$1\frac{3}{4}$		
2	14	$1\frac{1}{2}$	$1\frac{3}{4}$	
3	12	$1\frac{1}{4}$	$1\frac{1}{2}$	
4	10	1	$1\frac{1}{4}$	
5	8	$\frac{3}{4}$	1	1
6	6	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$
7	$1\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$
8	3		$\frac{1}{4}$	$\frac{1}{4}$
9	2		...	...

The fertility of the soil of this country is chiefly dependent on its power of imbibing and retaining moisture, and this quality is mainly affected by

its depth when it exceeds 3 feet, the fertility is not materially affected The deteriorating influences are, mixtures of nodular lime stone or kunkur, and coarse sand, loose or stiff soil, excess of moisture, and liability to be swept by freshes, this system only shows the capabilities of the soil, not its productive powers, which depend on the influence of climate and irrigation

Climate does not affect all soils alike, a change from a dry, to a moister, climate approximates the productive powers of the higher and lower descriptions, the latter, however, benefitting more from the additional moisture than the former

Irrigation augments as the productive powers of the soil, it is an important element in fixing the assessment of the land for which it is available

Irrigated land is usually distinguished by the terms garden and rice It may be divided into that watered from wells, from *bundarras*, or from tanks, or from wells combined with either of the latter

Land watered from wells is assessed according to the class of soil, the supply of water in the well, the depth of the well, whether the water is good or bad, whether there is any extra land to allow a rotation of wet and dry crops, and the distance of the garden from the village

A good well of moderate depth will irrigate from 4 to 6 acres of inferior garden crop

The assessment on garden land irrigated from dams or tanks is dependent on the quality of soil and the supply of water On land partly watered from a well and partly from a tank, the chief source of supply is ascertained, and allowance made accordingly

The classification of soil is modified in detail to suit the peculiarities of different districts

The full amount of assessment fixed on land may be understood from the following example —A field near a village having every advantage as to soil of the 1st order, a well, &c, is put down thus per acre —

	RS	A	P
Land, 1st class, 1st order,	1	0	0
Proximity to village,	0	8	0
Any other advantage, as near a nullah allowing irrigation from kutcha bunds,	1	0	0
For well,	1	8	0
Total per acre,	4	0	0

The ryots pay their land assessment by instalments, the time of col-

lection being after they have had the opportunity of carrying the produce of their land to market

Government can take any land, *inam* or *merass*, when required for public purposes, compensating the owner, by the grant of an equivalent piece of ground in another place, or paying him the money value Small strips required for roads or water channels are not taken into account as they are considered a general benefit, unless any particular improvements made by the ryot are interfered with, contractors for public works, in opening up stone quarries, digging earth and moorum beyond the strip of land granted by Government, must make their own arrangements with the local land-holders, the village authorities being bound to afford every assistance

Water-rates —At present it is not the practice to have a distinct water rate, the land being assessed at an amount which takes in the advantage of irrigation, this is equivalent to the difference between the dry crop land assessment and the garden crop cultivation For instance, *jeraet* land, similar to class 4, and 1st order, is assessed, including ordinary advantages, at Rs 1-12 per acre, and *baghaet* land, 1st class, 1st order, in like manner, at Rs 4 per acre, as irrigation would make an approximation of produce the difference of assessment (Rs 2-4) would be due to the water supply Allowing this amount where the ryot has to raise the water at a considerable outlay, what would be the value of a water supply which would cost him no labor? This, as a matter of course, would be variable according to the nature and productiveness of the soil, its situation, the habits of the natives and their system of cultivation

In the Hyderabad (Deccan) districts, many hundreds of square acres of land, with a surface soil of not more than 4 inches in depth, and simply composed of the detritus of laterite, the ryots, a hard-working race, familiar with the benefits of irrigation, and who cultivate rice to a considerable extent, willingly give Rs 7 for water alone, sufficient to raise two crops, there is a saying among them in allusion to their soil, "Give us only water and we will raise our crops on our cumblys"

In many parts of the country where the ryots have noticed the effects of irrigation in neighbouring districts, they have petitioned for water to carry out baghaet cultivation, and offered as much as Rs 15 per acre, and Rs 1 for one watering to an acre of rubbee crop, just when it might require it, or when the water would have the effect of either saving the crop, or, when it was in ear, increasing the produce one-fourth

In Lombardy the average cost to the cultivator for the watering of one acre of land is about four times as much as is paid by the Indian ryot, the rate being determined by the quantity and duration of flow and the crop produced, the rate for one cubic foot of water-flow per second per annum being about Rs 2,750, or Rs 17 per acre

In the N W Provinces, a water-rate is levied in a similar manner, a distinction being made between natural flow irrigation and artificial irrigation The following are the present rates —

Class	Nature of crop	Per acre irrigated by						Per
		Natural flow			Machinery			
		R	A	P	R	A	P	
I	Sugar-cane, gardens, and all lands taking a supply throughout the year,	5	0	0	3	5	4	year
II.	Rice, tobacco, opium, vegetables, and singharras,	3	0	0	2	0	0	crop
III	All *rubbee* crops, indigo and cotton,	2	4	0	1	8	0	crop
IV	All *khureef* crops not specified above,	1	10	8	1	0	0	crop

The number of waterings to each description is thus prescribed for the Nugeenah canal works

1 Fruit gardens,	8	waterings per annum	
2 Hemp,	5	„	per crop
3 Rice, sugar-cane, indigo, tobacco, cultivated grasses and herbs,	4	„	„
4 Cotton, wheat, barley, and all other grains and pulses,	3	„	„

The foregoing classification and numbers of waterings would not be adapted to the crops of this Presidency Our garden land embraces the cultivation of fruit trees, plantains, pan, vegetables, ground nut, sugar-cane, rice, &c, which in a certain time require a certain quantity of water, a 4 months' crop of rice taking half a cubic yard, and an 11 months' crop of sugar-cane taking 1 cubic yard, per square yard, of cultivation

In Madras, the water-rate is included in the land revenue, which is

dependant to a considerable extent on the selling price of rice, in some districts this amounts on each acre of cultivation to two-fifths of its produce, or on rice crops to about Rs 4¾ per acre, occasionally as high as Rs 8, if Rs 2 is the dry crop assessment, the price for water alone must be Rs 6 per acre If assessment were thus made on every description of crop, the amount from sugar-cane cultivation at the same rate per acre would be about Rs 60

Water Supply and Distribution.—The supply of water to a tank project is dependant on immediate local circumstances, except where its natural drainage is combined with a supply from a neighbouring stream, when it is termed an inundation tank Irrigation from perennial streams depends on the area of drainage and the volume of flow, this is affected in different ways The Indus and Ganges, draining Northern India, receive the melted snow from the Himalaya range, the Godavery and Kishna draining Southern India, and running from west to east, are flooded by both coast monsoons

The fall of rain varies in every locality In Bombay and along the coast it may be taken at 70 inches, along the Ghauts upwards of 100, above the Ghauts about 30 This quantity gives the usual result, that the most rain falls on hill sides, and that more rain falls at the foot of a hill than on the top It is thus accounted for the heavy monsoon clouds floating over the low coast at an altitude of about 1000 feet strike the Ghauts and discharge their contents, while the lighter portions of the cloud pass over At Mahabuleshwar a fall of 1 inch per hour is not unusual, and at Madras in 1846, 17 inches fell in 24 hours

The area of the watershed may be easily obtained as well as the annual fall of rain, but the drainage supply can only be taken on a rough calculation, the most correct way is to take the flood discharge at the proposed bund crossing, the average fall of the bed of the channel, the duration of flow of that volume, the extent of the rain-fall, (gauges being set in different parts of the watershed,) and the mean fall in a certain time, this will give sufficient data to work on When the fall of rain only is taken, allowance must be made for absorption, this quantity depends on the nature of the soil and its level above the drainage outlet Hills absorb but little moisture from their impermeable formation and the water running off rapidly In the plains, where the drainage is less defined, the soil deep and loosened by cultivation, not more than one-third of the fall runs off The first

showers of the season are generally sufficient to fill a tank, as the ground is too hard to absorb much moisture, consequently it drains off

As a general rule, 12 inches of the annual fall is allowed for storeage, or, in round numbers, 1,000,000 cubic yards to a square mile of watershed.

It is a great object that a tank bottom should be as sound as possible, if very porous, the water is rapidly absorbed, and the wells for some distance below the bund, are kept continually full, when the ryots are thus benefitted, they should be charged to the extent of half the balance remaining on the natural irrigation rate

Flood water carries down more or less soil in suspension according to the description drained It has been calculated that the Ganges deposits are equal to $\frac{1}{200}$th of its volume, and the Nile $\frac{1}{120}$th Although silting up does not go on very rapidly, as shown in the Cauvery Pauk tank in Madras, the bed of which was raised only 12 feet in 400 years, provision however should be made for carrying it off, this is done by constructing scouring sluices in the bottom of the bund, as the bed dries, the deposit is raked up, and the first freshes allowed to scour it away In some parts of the country, where cultivation of a superior description is carried on, the ryots use the silt as manure, it is particularly valuable in renewing the soil of *pan* gardens Very little deposit passes through an escape weir as it only carries off the surface water.

A great loss of stored water is sustained through evaporation, shallow tanks should never be intended to hold more than one crop of water, not an annual supply Deep water does not lose so much by evaporation, and when there is a great spread, a portion is recovered by the heavy fall of dew Aquatic plants, which grow thick from the bottom, as the rush and water lettuce, are injurious to the tank, while those which spread on the surface, as the lotus, prevent a great deal of evaporation When water is not deeper than 7 or 8 feet, the rays of the sum can penetrate to the soil, and the growth of aquatic plants is the consequence

The usual quantity admitted for evaporation in calculating the water storage is half an inch in 24 hours, or from the annual supply about 6 feet; this great loss may generally be compensated in tanks near high ground by the small streams which sometimes flow throughout the hot season

A standard should be erected in the deepest part of a tank having a scale of feet cut on it, and at every 5 feet vertical stones let in along the

corresponding contour round the basin, they assist in calculating for the distribution as the supply begins to get low

The immediate distribution from a tank is by means of irrigating sluices, *calingulahs* or syphons, the quantity being calculated by the height of the head of water and the area of the discharge orifice

A calingulah is a drain through the base of a bund, having two vertical bends, the one on the inside having an orifice regulating the quantity of discharge, which is done in a primitive manner by a conical plug attached to a pole fitting into a conical hole in a slab, and raised or lowered as required, the bend on the outside having holes in its sides regulating the height of the distribution

The distribution channels are either of masonry, or, if the soil admits, are only excavated When the flow is not sufficiently high, basins are supplied and the water lifted to the required height artificially If the height exceeds 10 feet, *motes* are used, worked by bullocks A mote holding 4½ cubic feet of water worked by 4 bullocks, will lift that quantity to a height of 25 feet on an average 63 times in an hour; or in a working day of 8 hours, constant labor, 2,268 cubic feet, being a spread of water nearly half an inch deep over 1 acre of land, at a cost of about three-fourths of a rupee.

When the lift of water is up to 10 or 15 feet, the *piccotah* is used, this is a standard with a cross lever attached to the top, a bucket being suspended from the long arm, and the short arm weighted heavy enough to raise the bucket when filled with water A man walking up and down the long arm causes it to dip or lift, if he is expert, this operation can be performed 10 times in a minute, the quantity at each lift being about 1 cubic foot, this, with 8 hours' labor, will give 4,800 cubic feet, or a spread of water about 1 inch deep over 1 acre of land for 6 annas

When the lift is not more than 3 feet, bailing baskets, worked by hand ropes may be used They hold about half a cubic foot, and are swung by 2 men, on an average 38 lifts can be made in 1 minute, allowing 6 hours in a day at this laborious work, we get 6,840 cubic feet, or nearly 2 inches spread of water over 1 acre for about 6 annas

Survey Operations for a Tank Project—On entering the field, a central position, or one near the bund site, should be taken up, and the first few days occupied in making a perfect reconnaissance of the whole of the ground, both above and below it, particularly examining the line on which the work

will stand After this has been done, and the examination proving satisfactory, the extent of the watershed or drainage area is then to be ascertained by traversing its boundary, leaving marks where fixed points are required in the survey, and either carrying the survey round the boundary with a prismatic compass and chain, or obtaining the several points by triangulation Where a watershed exceeds a few miles in area, it is a great saving of time and is sufficiently correct for the required purpose, to trace this area from the large *talooka* maps, the ranges of hills and the direction taken by the streams, distinguishing the extent of drainage in any particular valley

Presuming that the annual fall of rain is known, and data for the quantity of drainage arrived at, the result is shown in cubic yards as the water supply available for storage, in the mean time, if there is a small stream passing through the valley, its discharge should be ascertained

After ascertaining the available supply, the next matter to enter into is the size of the tank This is a question which can scarcely be brought to rule, as it is governed by so many extraneous circumstances A great consideration is depth of water, but other points should not be overlooked in obtaining it The spread of water depends on the height to which the bund is raised, and in a project having a limited drainage area, the height of the bund is determined by the required capacity of the basin The most economical height on gently undulating ground where there is a natural and long slope to the rear, is from 10 to 25 feet, in the first instance the collected water is not used for annual cultivation, but to afford moisture to one crop below the bund and well saturate the soil in the basin, which is cultivated, as the water is drawn off In hilly country, the site is generally on a small stream passing between the spurs of a hill range, where the section on the bund line is short, the fall of the ground in the basin is rapid, and depth of water obtained without a great spread, it is as well to run the bund as high as possible if it does not interfere too much with the return, bearing in mind that every foot in height may require an addition to the base of 6 feet, if it is an earthen dam, in some cases when the gorge is narrow and the stream affords about a 6 months' supply, a masonry wall of a moderate height may be constructed, strengthened by counterforts and allowing an overfall for surplus water A bund should not be raised unnecessarily high above the line forming a basin equal in capacity to the supply, nor should it be raised to such a height that the spread of

water will swamp villages or valuable property, without weighing well the loss of revenue and the amount to be expended as compensation to the proprietors, with the probable return of the project. If the bund is made too low, only retaining a depth of about 8 feet of water, and the bed of the tank is not intended for cultivation, the sun's rays penetrating to the soil through that depth encourages the growth of aquatic plants, and the work in a few years silts up and becomes almost useless, besides which, there is a considerable loss from evaporation.

The Engineer guided by experience, from a guess height on one side of the proposed line of bund, sets up his levelling instruments, takes a direct dead level to the opposite side, and fixes on both points prominent marks, this represents the level of the overflow line. From these points, three trial contours are run, one at the instrument height, one 5, and the other 10, feet below it. If the starting point commands a view, as is generally the case, of a greater portion of the intended basin, and as the trial contours are not required to be particularly accurate, four or more men with the sliding vane staves, the vanes fixed at the line of collimation height, are sent into the field in different directions to take up dead level points, being directed by signals into their true position, the Engineer in fixing them guessing the distance and allowing for curvature by the stripes in the vane, the width of which he knows, on each of these positions heaps of stones or earth are raised, and marks set up. By shifting the instrument to any of the commanding fixed points, others in different parts of the field may be filled in, in like manner, and the direct lines of the upper contour completed. This line can then be surveyed by Prismatic Compass and Chain, or by the bearing of the marks entered at the time of fixing them, taking one of the lines, that along the bund probably, as the base. This only gives a general outline of the basin, but sufficiently correct to answer present purposes. The section on the bund site is now taken, leaving marks at 5 and 10 feet below the dead level line for the contours to be run from, and at 10 and 20 feet for the points of issue for the irrigating channels. The 5 and 10 feet marks below the upper contour are fixed in all the sections which are taken, regulating the distances from the starting point, and as the closing point is reached, the levels are worked out, and the required complement of the level read from the staff. In order that no confusion may occur in distinguishing the marks of different contours, it would be as well to drive a peg along side each, and in a slit fix a piece of stout paper with a note on it.

Two cross sections should be taken parallel with the bund line, at equal distances apart, and three lines of longitudinal section, the centre one running through the deepest part of the basin.

The capacity of the tank with the proposed head is taken by roughly plotting its area from the survey notes, and instead of resolving it into regular figures, drawing transverse parallel lines at equal distances across it, taking the whole length of each line from boundary to boundary, and should it cross rising ground which will not be covered, the quantity is deducted. The mean of these lines gives the width, in the same way the mean length is obtained, the area being multiplied by the mean depth of the sections will give the capacity. If the higher contour gives too great a result, the lower ones are tried, and the height of the bund fixed accordingly.

The detail of the bund should next come under consideration, the section having been already taken, and the starting points for the irrigation channels fixed, the position of waste weirs, sluices, or other masonry works, should then be marked, the quantities for each portion taken out roughly, and fair working rates allowed according to circumstances, the estimate of probable cost being given in abstract.

The survey below the bund must be the next operation.—Its extent is bounded usually on both sides by the upper line of irrigation channels taken from the mark on the bund line 10 feet below the overflow. The length of channels is determined from the height and quantity of water in the tank above the opening, the water supplied to the higher channels is usually intended for bringing the rubbee corn crops to perfection, the area of land under that cultivation lying between it and the next channel, an allowance is made of one-fourth for land lying fallow or dry crop land, and 1 foot depth of water spread over the whole in 3 or 4 waterings, as these channels take the high and broken ground in the valley, they may be formed into links of connection with smaller dams across the hill side water-courses, this system is more economical and advantageous than constructing aqueducts to carry the water over small nullahs, besides considerably assisting the feeders to the fields.

Bagheat or garden land cultivation, requiring an annual supply of water, if bounded on each side by the second channels, taken, at say 10 feet below the first, and closes towards the level of its natural drainage, the lengths of these channels are calculated in the same way as those on the higher ground, an allowance of 1 cubic yard of water being made to each square yard of land, admitting no ground as fallow.

The operation of running and levelling the irrigating channels may be performed at the same time, the bearings of the several points being taken from the compass attached to the level In tracing these lines, a fall must be allowed, if they are small, 2 or 3 feet in a mile will do, if of a moderate size, from 1 to 2 feet, the larger they are the less fall is required, there are other points which regulate the fall To increase the discharge, the fall is increased, as also to prevent the growth of water plants, it must not however be carried to excess, especially through loose soil, as it will scour and injure the channels, after taking a dead level, the distance is measured, and the staff shifted lower until the allowance for the fall is read, the observation is then noted Marks should be left at each point, if possible on the divisions of fields, great assistance being derived by doing so in filling in the detail of the survey, which can be done from the village map

Where channels run into broken ground, the line of least cutting should be taken, and no attempt made to force difficulties by taking direct lines when a favorable detour avoiding them is presented

The width of the channels is determined by their length and fall, bearing in mind that each acre of cultivation may require a spread of water of from 1 to 2 inches in depth every 7 days

The field work may now be considered completed sufficiently to prepare a report and present sketches of the project, but before leaving the locality, the extent and character of the cultivated land or other property, as wells, houses, &c, lying in the basin of the proposed tank which will be lost by the spread of water, must be enquired into, and an estimate prepared showing the amount of remitted assessment and the compensation the proprietors are entitled to The requisite information as to the soil, &c, can be obtained from the Patells or Koolkurnies of the villages in which the tank is formed, with the assistance of the village map, upon which the outline of the tank can be traced, the numbers of the fields, &c, within its boundary being noted A reference is then made to the Village Land Register, this will furnish the names of the different tenants, the class of ground and the amount of assessment on it As the Engineer may be unable to decide upon the amount for compensation, and consequently cannot frame the requisite estimate, he should insert a Memo to that effect in his report, and submit, with the other estimates, a tabular statement of the numbers of the fields

The plans to accompany the report on a project should be only in out-

line or tinted, one sheet showing a general view, this can be traced from the Talooka Map, the area of the surface water from the level of the over-flow being tinted blue and the lines of irrigation channels shown in the same color

One sheet showing the spread of water and the fields, &c, covered by it, this can be traced from the village map.

One sheet showing the plan of the Bund site, with the general design projected on it, and tinted according to the character of the work, immediately beneath it, should be the section on the Bund line, the ground tinted with Burnt Sienna, the level of overflow a blue line, and dotted blue lines for the level of the water at the different outlets, the elevation of the Bund being shown in dotted ink lines, and one sheet of longitudinal and cross sections through the tank basin tinted in the same manner, the section scale for ordinary sized projects being 200 feet to an inch Horizontal, and 20 feet to an inch, Vertical

(To be Continued)

No CLXXXII

MARKUNDA RIVER WORKS.

Report on Tree Spurs and Embankments constructed to control the floods of the Markunda River, Punjab

From the Secretary to Punjab Government, P W Department, to the Government of India 25th November, 1867

THE sanction of Government of India was communicated in March last, to an estimate, amounting to Rs 62,575, for an embankment and spurs to regulate the flood-waters of the Markunda river, and it was requested that a report on the action of the works should be submitted after the close of the rainy season

I am desired to forward copy of a letter from the Executive Engineer, giving the required Report, and making certain proposals for the protection and extension of the works already executed

The Executive Engineer has described the works and the results of this season's floods very clearly, and the proposals he makes are approved by this Government

With respect to one of the proposed arrangements, a small modification of Mr Falkmer's plan appears desirable. For the protection of the right bank of river near the bridge, a spur running out obliquely from the high bank at A (that is directed from that point towards the right abutment of the bridge), and of such length as to extend 200 feet beyond the present channel, appears preferable to that proposed at B. It is, of course not easy to determine with confidence, from the plan only, that this will be better. The Superintending Engineer will be requested to examine the question on the spot with the Executive Engineer, and to report accordingly

From Executive Engineer, Bridges and Branch Roads Division, to Superintending Engineer, 2nd Circle, Punjab 31st October, 1867

The work was practically completed before the rains set in, and as the floods were extraordinary, the result may be relied on as a practical test of the efficiency of the means of protection adopted

During the highest floods of 10 feet, the depth of water along the main bund varied from 2 feet on the high land, to 6 feet in the overflow channels, the former places, not being protected, were slightly washed with the wave, but in the latter, being protected with fascines, no injury whatever has been sustained. The clay spur, being similarly protected was not injured, but the rapid current round the masonry head caused a scour about 6 feet deep, no damage, however, resulted, the foundation being 9 feet deep

The Motasootee Escapes, or overflow channels, have been silted up an average depth of about 9 inches, at this rate they will disappear altogether in a few years, provided, of course, that the bund remains intact The zemindars have already commenced to till the larger one, which shows they appreciate the result

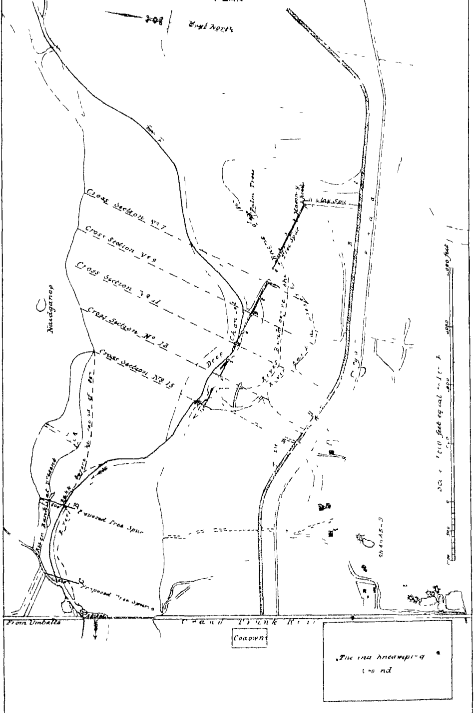
As the ultimate protection of the bund depends solely on the maintenance of the tree-spur, a careful consideration of its details and action is necessary Before going into details, a short sketch of its construction will be found convenient, and prevent the necessity of referring to previous correspondence

The anchor wells are 300 feet apart, 7 feet diameter and 28 feet deep below bed at site In the deep channel an additional well (No. 5) was sunk, to resist the greater force of the current at that place The well masonry is $1\frac{1}{2}$ feet thick, the inside being filled throughout with concrete, in which five iron-bars of 1 inch diameter are inserted These bars are fastened together below, two pass up the centre of the well, and three at equal intervals between the masonry and concrete They are again brought together at top and pass through double rings, through which the chain passes, and where it is permanently fixed by means of an iron-clamp inserted between the rings

The chain (of $\frac{3}{4}$-inch link) was stretched moderately tight, just sufficient to prevent its being lost by sinking in the quick-sand during floods The trees were tied on with galvanized iron-wire, about 10 feet to each, they covered an average length of 3 feet of chain, exclusive of small trees and branches which were interwoven wherever the trees were thin

MARKUNDA RIVER WORKS

PLAN



The spur was thus completed when the first flood came down, and just above the trees, the water attained a depth of at least 4 feet almost immediately The trees were then floated, thus destroying any resistance that would have accrued otherwise from their friction on the ground The chain, subject to the combined forces of the current, and that due to floatation, gave way near well No 6, and, with its trees complete, was stranded in the position shown on the drawing

The water passed out between wells Nos 13 and 14, carrying away the chain and trees in pretty much the same manner This flood did not alter the channel materially, as the chain gave way before sufficient water had collected to pass off in front of the trees, and, with the exception of a slight alteration due to the cutting away of the bank inside the trees, the deep channel remained as before

When the water subsided, the upper breach was repaired with a double chain, the part on the high bank between wells Nos 1 and 4 having been taken up for the purpose, and its place supplied with a rope

The chains were independent of each other except where attached to the well, each carried half the original number of trees, and of course a proportional strain

The next high flood destroyed both chains, and also broke 6 feet off No 6 well. The piece was taken down-stream as far as the chain allowed, where it still lies buried in silt The five iron-bars, masonry, and concrete were broken off quite short, and although the rods were only common English bar-iron, they did not show any flaws which might account for the failure The masonry was evidently good, otherwise the piece would have broken up when being knocked about in the current

The chains on this occasion, however, resisted the current for a sufficient time to attain a success, which, though only partial, was very satisfactory The water flowed down in front of the trees along the right bank, and in an intermediate channel, which again, uniting below the trees, flowed quite square through the bridge The deep channel under the right bank just above the bridge became silted up, and a proportional cutting away took place on the opposite side

After the high flood had passed off, the deep channel remained outside the trees, where it still continues, but the channel along the right bank, opposite the tree spur, got silted up when the stream returned to its old

channel just above the bridge The broken chains were found to be inaccessible, having got covered with about 6 feet of silt, but the breach was repaired several times subsequently with ropes, to which were attached small trees and brushwood These were always carried away by the next flood, but they caused a considerable deposit of silt at the back, as shown on the cross-sections

Towards the end of the rains a small flood of about 4 feet broke the chain near well No 11, but this merely let the water inside the spur at the breach, and did not otherwise affect the bed of the river

The space between the dotted and hard lines on plan shows the extent of bank cut away behind the tree spur, at the upper end it is very large, owing probably to the broken chain, after being stranded, having directed the current right on to the bank at the place The cutting, however, is more apparent than real, as a great portion of it has got silted up again (*see* cross-sections), but this silt is not nearly so effectual as the natural bank in resisting the action of the current

The right bank near the bridges has suffered considerably also, and the wing-wall bund has all but disappeared, what remains must be protected to save the bridge itself Apparently, the bridge remains uninjured, though a deep and probably dangerous scour occurred on the up-stream side as already reported, the crack in the north abutment (which also runs through the north-east wing-wall) does not seem to have increased

The alteration which the bed of the river has undergone is clearly shown by the cross-sections, that at No 7 well shows the large deposit of silt that has collected in the old channel, with a proportional cutting away towards the centre and right bank, the other cross-sections show a continuation of the same The deposit of silt just at the breach, and for some distance up-stream, is much greater than that shown on cross-section, No 7 being nearly lined with the natural bank

The total result is as follows —

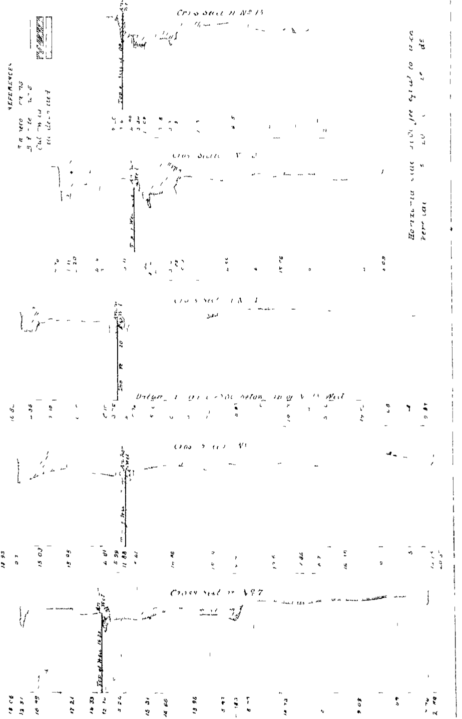
The main bund has proved effective, and saved the city of Shahabad and adjacent country from inundations

The tree-spur has been broken in three places, and one anchor well destroyed, this has allowed the bank behind it to be cut away extensively, but in spite of failure, the spur has altered the deep channel, and turned it away from the bund

The trees on the unbroken parts of the chain have sunk down and are

MARKUNDA RIVER WORKS

(Cross section at the Tree Spur)



partially covered with silt, they have also collected a large quantity of grass jungle, brushwood, &c A large quantity of silt has been been deposited inside the trees.

The right bank near the bridge has been extensively cut away, and the deep channel still remains under it

The failure of the tree-spur was due to three causes—*first*, the chain was too weak, *second*, the anchorage was insufficient, and *third*, the trees were partially floated, and thereby increased the strain on the chain, as well as the risk of being carried away themselves independent of the chain, had the latter remained unbroken

To remedy this, a stronger chain and more anchorage will have to be provided, the latter can be easily effected by sinking an intermediate well in each 300 feet space in the bed of the river, this will require eight wells, the holding powers of which may be increased over the old ones to any extent, by putting in a greater number and thicker rods

It is quite evident that the anchorage must be perfect, otherwise, no chain could resist the current after a lot of the wells had given way

It will be difficult to prevent the trees floating, but a bank of earth thrown well in through them will effect the object temporarily, the trees will prevent its being washed away for some time, and it will at least stop the first rush of the water, which is of considerable importance The cost will be trifling

The details of repairs will be similar to those of the work already executed, and need no further remark

As no extension of the work is necessary to protect the bund, the next consideration is how to protect the right bank near the bridge This cutting is in no way connected with the tree-spur, as would appear from the fact that it ceased when the tree-spur was really effective, but independent of this, it must be considered an extension, and a necessary one also

To protect it with a continuous spur would be expensive, as it should extend from the abutment of the bridge to the high ground at A, a length of 3,000 feet Two spurs at B and C, of 600 feet each, will be just as effective and much cheaper, each would protect at least double its own length, besides causing a large deposit of silt at the back, but in this case it would be advisable to put one its own length from the bridge to protect the wing-wall more effectually

Each spur will require five wells, sunk 20 feet deep, as in the former case, the chain, trees, &c, should be also the same

The chain ordered to be used for repairs, was one of $1\frac{3}{4}$ diameter of link, the cost of this will be about Rs 4 per foot, and taking the sanctioned rates for the other work, the cost will be as follows —

REPAIRS TO OLD SPUR

		Rs
3,900 Running feet of chain, at Rs 4 per foot,	=	15,600
8 New wells complete, at Rs 450,	=	2,060
3,900 Running feet of trees tied on, at Rs 1-8,	=	5,850
3,900 " of clay bank on trees, at 4 annas,	=	975
Total,		24,425

EXTENSION TO PROTECT RIGHT BANK

1,200 Running feet chain and trees, &c, complete as above, at Rs 5-12,	=	6,900
10 Wells complete, at Rs 450,	=	4,500
Total,		11,400

aggregating a total of Rs 35,825 for the whole work

No CLXXXIII.

DEMOLITION OF FORT KOTAHA

By R G Elwes, *Executive Engineer*

The demolition of buildings by gunpowder seldom falls within the province of the Civil Engineer, and but little information upon the subject is to be obtained from books, except in purely military works, not usually contained in his professional library The following notes have been drawn up, in the hope that they may be of use to any one suddenly called, like the writer, to perform such a duty without previous experience and with scarcely any information to guide him They do not pretend to offer any thing novel to a military reader

In September 1864, the writer was directed, under the orders of Government, to proceed to Gurhee, or Kotaha, about 20 miles north of Umballa, and to destroy the fort at that place, belonging to a Mussulman chief, known as the Meer of Kotaha

Upon examining the place, the fort was found to be an octagon of somewhat more than 100 feet in the side, with round towers or bastions at the angles There had been an outer line of defences, but these were destroyed in 1857, and then ruins had filled up the ditch, if there had been one The fort stood upon an elevated spot commanding the whole country round, and had reputation among the natives It was considered by them to be the third strongest in the Punjab, and Runjeet Sing is said to have come down himself with an army to take it, but after marching round it, he went back again An attempt had been made before the writer's arrival by the civil authorities, to destroy the gateway by exploding an open barrel of powder under it, but this had no effect The failure of that

attempt, with the local reputation of the fort, and the fact that the late owner was encamped opposite the entrance, watching the proceedings, made us particularly anxious that there should be no mistake the second time

The walls of the fort were from 26 to 30 feet high, and consisted of an outer facing of boulder masonry, in lime mortar, 6 feet thick at bottom and $2\frac{1}{2}$ to 4 feet at top, then an earthen rampart about 10 feet thick and 12 feet high, then another masonry wall about 3 feet thick, then a row of mantled casemates about 16 feet wide, making a total thickness from outside to inside of about 35 feet at bottom Above the earthen rampart was a line of barracks and store rooms, about 13 feet deep, and their flat-roofs formed a platform for musketry, protected by a parapet 3 to 4 feet high The details, however, were in no two places exactly alike—they will be understood from the sketches

The gateway had been furnished with flanking defences in the usual native style, but these were destroyed in 1857 Upon entering the fort, the two faces to the left were occupied by rows of barracks and store-rooms To the left front, were the public rooms and palace of the Meer, arcaded buildings surrounding a courtyard, and having an underground series of vaults supported by thick pillars, which gave us more trouble than anything else Upon the face opposite the gateway were offices and servants' houses, to the right front three faces were occupied by the zenana and a small mosque, and immediately to the right of the entrance was the guard-room, &c It was determined to destroy the curtains and bastions first, by a series of moderately large charges, and to attack the interior buildings afterwards by small mines in their walls

The first seven mines were fired with native powder made for the purpose by the Tehsildar, which answered very well, with an addition of 10 to 15 per cent to the calculated charges, the remainder of the mines were fired with magazine reserved powder

Shafts had already been sunk in several of the ramparts and bastions by the Tehsildar, and, to save time, they were made use of, though they were in some cases rather too far apart, viz, at $2\frac{1}{2}$ lined intervals, which would have required a larger charge than the vertical resistance available allowed, to make them completely effective

The first thing done was to make up 600 feet of hose, 1 inch diameter, of "gára" cloth, double This hose was used to pass through the tamping,

smoke The natives were excessively astonished, they had ridiculed our proceedings at first, and now probably expected a great bang and a crack or two in the masonry, the sight of a solid tower 22 feet in diameter and about 30 feet high melting down into rubbish as if by magic, had a great effect on their imaginations, as we intended it should

Two small portions of masonry were left at the re-entering angles, and the arcade at the gorge of the tower was undisturbed In No 2 bastion, the charge was increased to 150 lbs with the same L L R of 10 feet, to get rid of these angles The object of destroying the bastions first, was to deprive the curtain of their support, it being backed up behind by a mass of buildings

In No 1 curtain, 4 mines were placed, as shown in the general plan The formula employed was $\frac{LLR^3}{4}$, increased by 30 lbs. in the case of No 3, on account of the solid mass of masonry and earth on three sides of it. The mines were fired from one focus, and the hoses arranged to be of the same length, but the explosions were not exactly simultaneous, it was found almost impossible to make them so, and eventually the plan was adopted of firing the mines successively, the connecting hose was made to burn rather slowly by burying it in a trench. In this way each mine helped the succeeding one by destroying the supporting masses on one side of it

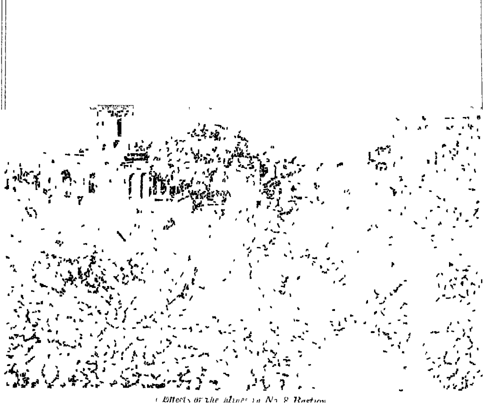
Bastion No 3 was next destroyed by mine No 7, which was placed further back so as to give a L L R $=$ 14, in order to destroy the rear masonry, the charge was $\frac{LLR^3}{8} = 343$ lbs, and the effect excellent, there was a slight report, but no projection of stones, and the destruction was very complete

The three mines, Nos 8, 9 and 10, were arranged with L L R $=$ 10, and charge $\frac{L.L.R^3}{4}$, in order to destroy the casemates in rear, which was effectually done, but the depth of the shafts (in earth) was only 13 to 14 feet, and although 3 or 4 feet of rubbish had been piled on top to increase the vertical resistance, this was not sufficient, No 4 mine shot up a quantity of rubbish into the air, and the site of each was marked by a distinct crater.

In all the mines, the hose was protected where it passed through the tamping, which was in all cases of earth, by two halves of a split bamboo tied round it, and it was curious that, when nothing else was projected up-

DEMOLITION OF FORT KOT[illegible]

Destruction of No. [illegible] Bastion



Effects of the Mines in No. 8 Bastion

wards, these bamboos were always shot up to a great height, like a ramrod out of a gun

These three mines were intended to go off simultaneously, but No 10 hung fire for about five minutes, the hose having been disturbed by the other explosions It is one of the advantages of firing a series of mines successively, instead of together, that the explosions can be counted and there is less risk of accident from one mine hanging fire without being noticed.

The *fourth* bastion requires no special notice, but the *third curtain* was a puzzling one to arrange Mines Nos 12, 13, and 16 (*see* plan), were sunk as usual in the solid earthen rampart, but in the space between them, the rampart was occupied by very solidly built casemates, with the level of their floor about 4 feet above the ground outside the fort Behind these was a second row of casemates also every solidly constructed, and as it was desirable to destroy all this boulder masonry completely, to save labor in breaking up large masses afterwards, the mines 14 and 15 were arranged with L L R = 11 feet, and 12 feet, and charges of 360 and 480 lbs, respectively (*vide* section on RS) These were the largest charges employed in the whole work

It may be here remarked that both in the present case and in blasting work of a different kind in the hills, the writer has found it bad economy to be sparing of powder A few pounds extra may save days of labor in breaking up and removing fragments afterwards, and it pays to use the largest charges that can be fired without a dangerous scattering of stones, &c

Holes were knocked in the crowns of the vaults over Nos 14 and 15, and through them, after the mines had been tamped, the vaults were filled with stones and rubbish, giving great vertical resistance

This series of mines was intended to be fired in succession, beginning from No 11, but the precaution of burying the connecting hose had not been used, and they went off irregularly, No 15 not at all, the hose leading to it had apparently been cut by a falling brick Only five reports were heard, but it was supposed that two mines had exploded together. The destruction of the whole face was most complete, and the failure of No 15 was only discovered by the writer's stumbling on the cut end of the hose, upon going, as usual, to see that all was right before letting the workmen return Wherever there was the least doubt about any mine having gone off, half an hour was allowed to elapse before any one went near the place,

and this interval was not a bit too long, for on one occasion when the half hour was over, and the writer went up to see why a mine had failed, it suddenly went off as he approached the spot, much to his astonishment

The small postern gate leading out from these casemates was apparently a secret entrance to the fort, the door was artfully concealed on the outside by bushes, &c Various dismal stories were told by the natives about this postern, which communicated with the interior of the zenana, and their tales received some confirmation from the discovery of an underground dungeon, beneath the vaults, the entrance to which was in the passage leading to the postern This dungeon had no opening into it except the door, and that opened only into the dark underground passage It was difficult to conceive a prisoner living in such a den, and it was with no small satisfaction that the writer saw the whole dismal place blown to pieces

In bastion No 5 and curtain No 4 the mines were arranged to go off in succession Hoses were led from each down the face of the wall, and connected by another hose buried in a small trench along the foot This secured an interval of several seconds between each explosion, and answered very well It was pretty to watch the connecting hose smouldering along the foot of the wall, and as it came opposite each mine sending up a fiery flash to the loop hole, answered almost immediately by the dull thud of the explosion, and the down-fall of the old gray rampart that looked so massive

The remaining mines in the curtains and bastions need no special notice, except that it was found that a vertical resistance of even 18 to 20 feet of earth was not sufficient, with LLR = 9 or 10 towards the face of the wall and charge $= \frac{L\ L\ R^3}{4}$, to prevent earth and stones being thrown up to a considerable height The charges were not decreased, as there was no danger from this, so long as stones were not projected laterally

The destruction of the buildings in the enclosure of the fort was at first attempted by jumping small holes in the walls at an angle of 45° to the horizon, at 2 line intervals, as recommended in military books But the plan did not succeed here, partly perhaps because the bricks were very small, and were apt to be knocked out bodily by the jumpers, leaving irregular holes very difficult to tamp It was found that jumping so many

small holes was tedious and expensive, and the mines often only blew out a piece of the wall, leaving its stability little injured; moreover, the small bricks were sent flying about to considerable distances in an unpleasant way. Some remarkable experience was gained as to the powers of good masonry to support itself in trying circumstances. In one case, two of the walls of a small room, about 12 feet square and 15 feet high, were blown clean out to a height of 3 feet from the ground for their whole length, except just at the corner, where a few bricks remained and supported the two walls until they were knocked away one by one by throwing stones at them, when the whole came down with a crash. In another case there was a row of three arches about 8 feet span; upon the top of them was a second row, and on the top of that, a wall about 1 foot high carrying a wide heavy cornice. This formed a cross wall of a house of two stories. The two piers of the lower arches were blown away, bringing down the *haunches* of the arches above, and turning the three openings into one; the whole wall was thrown about two feet out of the perpendicular, but it stood in this way for many days till the side walls were blown down.

The small mines having failed, 30 lb boxes of powder were sunk about 6 feet below the ground inside the principal angles; a chamber was formed well under the foundation, and after tamping the shaft, a large pile of rubbish was heaped up in the corner to increase the resistance. This was most effectual for ordinary buildings, but the vaults under the palace gave much trouble. It was of no use putting powder in the vaults, as there was nothing above but the floor of the audience hall, &c., and the charges would merely have blown a hole out of the crown of each vault. Jumper holes in the piers were tried and failed signally; eventually each pier was separately demolished by charges of powder buried under it, or by the crowbar.

The total expenditure of powder in the demolitions was about 15,000 lbs.

The writer cannot conclude this paper without drawing attention to the admirable qualities of the patent fuze, which seems strangely neglected in this country. About four years ago, every magazine and arsenal in India was written to for a supply of fuze; only two had it, one had 2000 feet, and one 60 feet only. We frequently hear of accidents from the want of it, and yet there is absolutely no drawback to it for civil works. The writer has used it extensively for several years, with ordinary care it *never*

fails,* never explodes prematurely, and while cheaper than the common plan of priming, it can be applied to much deeper mines. There may be special cases of military mining where it is inapplicable, but it has the great advantage of burning at a definite rate, and, at all events, its use would prevent such accidents as caused the death of two distinguished officers in the Crimea and in India, in returning to examine a common fuze which had hung fire.

APPENDIX

Tabular Statement of mines Exploded at Fort Kotaha (exclusive of those under 50 lb charge)

Number on Plan	L L R	Formula employed	Charge by formula	Actual charge	Remarks
	feet		lbs	lbs	
1	10	$\frac{(LLR)^3}{8}$	125	125	Bastion Native powder
2	10	.	125	150	Bastion 25 lbs added to allow for native powder
3	9	$\frac{(LLR)^3}{4}$	182	210	Curtain Native powder
4	9		182	180	" "
5	6		54	60	" "
6	9		182	180	" "
7	14	$\frac{(LLR)^3}{8}$	343	343	Bastion "
8	10	$\frac{(LLR)^3}{4}$	250	240	Curtain Magazine powder
9	10		250	240	" "
10	10		250	240	" Hung fire 5 minutes
11	13	$\frac{(LLR)^3}{8}$	275	275	Bastion
12	8	$\frac{(LLR)^3}{4}$	128	130	Curtain
13	9		182	180	"
14	11	.	333	360	"
15	12		432	430	" Hose cut, failed—fired afterwards with success
16	9		182	180	Curtain Hung fire 5 minutes
17	14	$\frac{(LLR)^3}{8}$	343	360	Bastion.
18	10	$\frac{(LLR)^3}{4}$	250	240	Curtain.
19	9	.	182	180	" Failed first time Hose cut by a falling wall, fired next day
20	10		252	240	Curtain

* The writer has seen touch paper burn up to, and go out in cannon powder four times in succession without igniting it, owing to the solution of saltpetre used for preparing the paper having been too weak

Number on Plan	L L R	Formula employed	Charge by formula.	Actual charge.	Remarks
	feet		lbs	lbs	
21	9		182	180	Curtain
22	14	$\frac{(L\,L\,R)^3}{8}$	343	300	Bastion
23	9	$\frac{(L\,L\,R)^3}{4}$	182	180	Curtain
24	8		128	120	"
25	8		128	120	"
26	8½		158	150	"
27	9		182	180	"
28	11	$\frac{(L\,L\,R)^3}{8}$	166	150	Bastion
29	8	$\frac{(L\,L\,R)^3}{4}$	128	120	Curtain
30	8		128	120	"
31	8		128	120	"
32	7		85	90	"
33	8		128	120	"
34	10		250	210	"
35-47					The record of these mines has been lost

Postscript.—The time occupied in the whole demolition was about two months, but the work was twice interrupted by illness, and was delayed by want of powder and tools, and by the writer's deputation on other duties There was no particular object in hurrying it, and being extremely anxious to avoid any accident or failure in such a dangerous undertaking, he allowed no more work to go on than he could personally supervise

R G E

No CLXXXIV

THE BHATODEE TANK

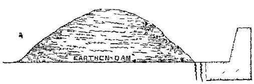
Report by the Superintending Engineer for Irrigation.

About 12 miles from the Cantonment of Ahmednuggur, are the remains of a very large unfinished tank, known as the Bhatodee Tank.

I have not been able to learn its history, nor is it I believe known; the work was conceived on a vast scale, and then appears to have been abandoned when well on to completion, perhaps from want of funds, but more probably from the subversion of the dynasty under which it had been commenced.

It is not one of the ruined tanks (of which there are so many examples in India) which have been breached after completion, but an unfinished work never brought into use.

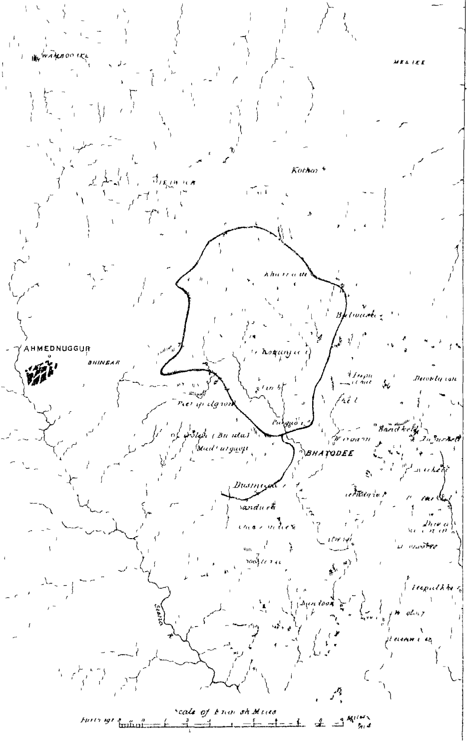
It is unlike, in one remarkable feature, any native work of the kind with which I am acquainted, viz., that at the deepest part of the tank, or where the feeding nullah runs, in addition to the



earthen dam, a masonry wall of vast strength has been built across the nullah bed, as above.

It is difficult to say what this wall was intended for, and how it was to have been finished off (because it does not seem to have any connection with the earthen dam which was thrown up some distance behind it). I

BHATODEE TANK



have known, in other cases, great and needless precautions taken at the point where the dam of a tank crossed the stream, and suppose this to have been something of the sort. As it is, at this point, or at the deepest part of the tank, there are two dams, the earthen one in rear and the masonry one in front.

The earthen dam is continuous, with the exception of the gap through which the nullah flows, the masonry wall has acted as a weir, and a deep pool has been excavated by the overfall. The said masonry wall is very far from complete, the foundations are in, and a part of the superstructure has been raised of greater or less thickness and height all along, with the exception of a notch or gap in the centre, corresponding to the gap in the earthen dam.

What masonry there is, is of the soundest and most excellent description. The earthen dam is about 50 feet high in the centre of the valley, but rises to a far greater height on each flank, it has been conjectured, that this arose either from an error in levels, which seems improbable, or what is more likely, that the project really contemplated raising the whole dam to a similar height, when it would have been of vast dimensions indeed, scarcely warranted by the supply of water available to fill it.

Projects for the completion of this tank have been mooted for many years, the subject was at length warmly taken up by Captain Meadows Taylor, then employed in a Political capacity in the neighbourhood. Assisted by Lieutenant Cotgrave of the Engineers, and a Civil Engineer, Mr Victor, considerable progress had been made in the necessary surveys, when other business intervened, the various officers were scattered, many of the plans, field-books, and other data, the result of their labours, lost, and the project again shelved, much to Captain Meadows Taylor's disappointment, who seems to have taken a most praiseworthy and scientific interest in the matter. It has now been resuscitated by the Irrigational Department, I trust finally, and that it will soon pass from the region of correspondence and project to a completed work, paying a good revenue to Government, and assisting in the general comfort and well being of the country.

The fact which I have before noticed, that in the lower part of the valley there are the unfinished portions of two dams, the one behind the other, has always puzzled those who have undertaken plans for its restoration. The question has naturally been—Shall the earthen dam be finished? or the masonry one? or a compound one be made with a part of each?

The earthen dam is of considerable height and continuous, with the exception of the gap left for the nullah to flow through Its completion is a simple work, and has the great advantage of making the whole dam a simple homogeneous work

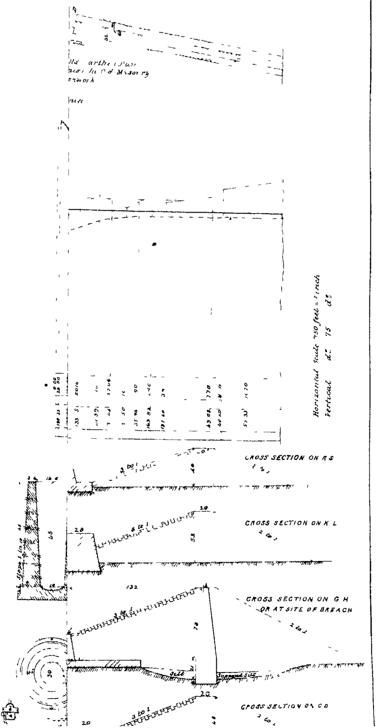
The masonry dam is so well built, and has such excellent foundations, that restorers did not like to see it wasted, but have proposed its completion to the full intended height and strength This however would lead to all the earthern dam lying in its rear being wasted, and to a very awkward junction between the ends of the masonry wall and the flank earthern embankments The new masonry, moreover, would never amalgamate well with that of centuries ago The compound dam has worse features than either, it has been proposed to complete the masonry wall, of too weak a section to resist the pressure of the water by itself, and to back it up by the rear earthen embankment thrown forward for the purpose To such a construction I have the greatest objection, to say nothing of digging up the well-consolidated earthwork in rear, a compound dam of materials of such different qualities as masonry and earth to resist an enormous pressure, and be at the same time subject to leakage and other contingencies, would never commend itself to me, I should always doubt their acting together sufficiently to ensure safety. Other ideas mooted, such as burying the old masonry in the body of the earthwork, are not worth remark

The plan I have resolved upon is, to my judgment, the best under the circumstances, it has the advantage of utilizing all the existing work, while the homogeneity of the bund is not interfered with

The existing earthern dam is to be raised to the necessary height with a width at top of 20 feet, a slope in front 3 to 1, in rear of 2 to 1 The front slope to be protected by dry stone pitching At the gap, in the first place, the hole excavated in the course of ages by the water falling over the unfinished wall is to be pumped dry, and the accumulated silt removed, it is then to be filled up with good material, a puddle wall being brought up from the bottom, where it must be carried into solid ground, to the top of the embankment, properly stepped into the solid mass of the old earthwork on each side

The only thing to be done to the masonry wall, is to fill up the gap in the centre by a revetment wall of moderate thickness We then have a line of beautifully constructed and solid masonry, with foundations sunk to a great depth across the nullah bed, on which to rest the toe of the

BHATODEE TANK



earthen embankment all along the lowest part of the valley where the pressure is the greatest, and the most danger is to be apprehended The work thus built will be stronger than any dam of the sort I have ever seen

The waste weir being the safety valve of a tank, should always be of the amplest dimensions, in this case the ground being suitable, and the expense moderate, a very large one has been designed, so large, that let the flood be what it may, even one of those *débâcles* of water that occur but once in a century, there will not be the slightest fear for the safety of the tank—no possible flood could rise more than two feet on its crest It might be suggested that the weir is too large, but there is no saving worth mentioning in making it smaller, and no other reason to do so, while so many otherwise well constructed tanks in India have failed from insufficient length of the waste weir, that I prefer to lean rather to the side of excess than scantiness of dimensions

The inlet tower has been simply copied from that designed and sanctioned for the Sholapore Tank,* now ordered to be constructed, any improvement or alterations that may be found of advantage at Ekrook will be adopted here also

In Lieutenant Abney's report, it will be seen that he calculates the whole cost of the tank at Rs 3,76,064 I think some of his rates are too high The principal alteration I have made, is in that for earthwork, where I have adopted "Rs 1-4-0 per 100 cubic feet, instead of 1-10-0" The former is the rate allowed for the Sholapore Tank, and will I think be quite sufficient, there is a great deal of spare earth which has been thrown up on what will be the flanks of the dam as now designed, which can be brought *down an incline* on a simple tramway very economically The estimated cost then, after the alterations made in my office, will be three lakhs

Lieutenant Abney calculates the revenue to be Rs 57,173, or more than 15 per cent on the capital expended, according to his estimate, or 19 per cent on it, as corrected by me I by no means say that this revenue may not be eventually obtained, but it is better not to be too sanguine in these matters

Mr D'Oyly the Collector of Ahmednuggur, in answer to a reference I made to him, says, "that Rs 6 for 12 months' irrigation, Rs 4 for 8 months, and Rs 2 for 4 months, should be standard rates on which the calculations of revenue should be founded" He also expresses a doubt about the

* *See* No CLXXVII of these Papers

projects affording monsoon irrigation in addition to the supply for 8 and 12 months

Now, on referring to the paragraphs he quotes in the Lakh Project Report, I find that Mr D'Oyly writes as follows —"I think the following would be very moderate rates—Rs 9 for perennial irrigation, Rs 5 for cold weather, and Rs 3 for monsoon irrigation" Lieutenant Abney assured me that the villagers whose land would be benefitted expressed their entire willingness to pay the above rates

With regard to the monsoon irrigation, Lieutenant Abney calculates that, with a minimum monsoon fall of only 16 inches, there will be, over and above the amount of water required to fill the tank, a supply for the 4 months' irrigation of 8,550 acres, while Mr D'Oyly calls 20 inches a scanty fall for the monsoon

The drainage area of the tank being 50 square miles, and its calculated content 660,000,000 cubic feet, a rain fall of 9 inches* only would fill it, and any fall over and above this, would be available for monsoon crops

However, to keep entirely on the safe side in the calculations of the revenue to be derived from the tank, let us neglect the monsoon irrigation altogether, but retain the rates of Rs 9 and Rs. 5 for the 12 and 8 months' supply

The revenue will then be as follows —

	Rs
12 months, acres 3,360, at Rs 9, .	30,240
8 ,, ,, 2,400, at Rs 5, .	12,000
	42,240
Allow for maintenance, . .	10,000
Net revenue,	30,240

or 10 per cent on an expenditure of 3 lakhs The maintenance charge ought never to be so high as the amount set down, a tank, when once well finished, needs little if any repair, and the canal is a short one with few masonry works.

In the above report, it is shown that we have a vast work of irrigation left us in an incomplete state by our Native predecessors, and that so much being already finished, we can with a profit obtain a magnificent

* $5280 \times 5280 \times 50 \times x = \frac{3}{2} \times 660{,}000{,}000$

then

$x = \frac{990{,}000{,}000}{1{,}393{,}920{,}000} = 9$ inches nearly

lake on a spot where, had we to commence *de novo*, the expense would make it hopeless, and that it does really seem a great pity to allow the fruits of so much labor to remain useless to the country We not only have the certainty of a liberal profit, but the pleasure of changing what at present is but a blot on the landscape—an instance of men's labor unprofitably wasted—into a work which will change the barren land into fertile fields, and remove what must be a reproach to us as long as left in its present state

Extract from Report by Lieut Abney, R E, Executive Engineer.

I have made the bottom of the canal line to start from a point 45 feet below the top of the proposed masonry dam, as nothing was to be gained by making it start from a lower point, except a very small quantity of water I found that by attempting to retain a larger body of water than I have done, that the revenue would not be increased in proportion to the expenditure, and I believe that a maximum of the former, compared with the latter, has been reached at the dimensions I fixed I find the content of the proposed tank to be 665,285,000 cubic feet of water, allowing 5 feet at the highest level for evaporation, I get 470,000,000 as the quantity of water available for irrigation, exclusive of the amount that flows into it during the hot weather, which is estimated at 5 cubic feet a second This 470 millions of feet gives about 23 cubic feet a second, and with the 5 cubic feet mentioned, give 28 cubic feet a second as the least available amount for the whole year round.

Taking the land irrigated at 120 acres a cubic foot, the amount available for perennial irrigation is 3,260 acres During the cold weather, 25 cubic feet a second flows Thus for 8 months' irrigation, 20 cubic feet a second is available, which gives, at 120 acres the foot, 2,400 acres more During the monsoon months the average amount of water that flows is 120 cubic feet exclusive of floods Now, it is calculated that the drainage area of the tank is 50 square miles, and the minimum rain-fall for 4 months is 16 inches, or 1,858,510,000 cubic feet. Taking two-thirds of this as flowing into the water-courses, we get 1,239,000,000 as the supply, which agrees with the gauging return of 120 cubic feet.

Now 660,000,000 cubic feet fill the tank, therefore I think we may assume that 570,000,000 are available for monsoon irrigation, which gives about 57 cubic feet During the 4 monsoon months, therefore, I take it,

that at least 57 cubic feet a second are available for irrigation, which, at 150 acres per cubic foot, gives 8,550 acres. Taking the rates of 12 months, 8 months, and 4 months' irrigation as Rs 9, 5, and 3 respectively (which are low rates), the resulting numbers of acres and amount of revenue are as follows —

					Rs
12 months,	acres	3,360,	amount,		30,240
8	„	2,400	„		12,000
4	„	8,550	„		25,650
	Acres,	14,310		Rupees,	67,890

So much for the revenue

I now come to speak about the dam The old masonry dam is made of beautiful work, the tank side, coursed, and outside, uncoursed and rough, and well adapted for new work to be added on to it It is of such an ancient date, that the chunam can scarcely be distinguished from the stone itself in regard to hardness and structure According to instructions, I have left all of it without making any additions to it, except the filling in of a gap, as shown in the plan

Rs 1-10-0 per 100 cubic feet have been taken for the earthwork, also Rs 8 for the pitching has been taken, as the débris of the old pitching may be worked up again with but little expense

The site for the regulating sluice has been carefully selected The form given to the "tower" I hope will meet with approval Two pipes of 3 feet diameter are used, which, it is calculated, are amply sufficient for the whole of the water to be discharged

The channel for egress of the waste water I have made with a breadth of 850 feet, according to instructions, and it will be quite ample to carry off the greatest flood

The canal line has been taken with 1 and 2 feet fall in a mile in the plan The first has been taken partly in order to give rather less cutting in some parts, and also to give a better fall to the distributing canals In one place it will be seen that a deep cutting of 24 feet is made This could not be avoided, owing to the great steepness of the river banks themselves, which forbade the idea of bringing the line to a position where the cutting would be more favorable The total length of the canal is $4\frac{1}{2}$ miles, and the cost, including the bridge, Rs 55,726, which gives about Rs 12,000 a mile

Six distributing sluices are to be constructed in the places which, during the progress of the work, may appear most fit

Owing to the difficulty of making agreements with the Government of the Assigned Districts, I have thought it advisable not to attempt to expressly irrigate any portion of the Nizam's Territory Should any of the inhabitants of Bhalooree, however, feel disposed to pay a water rate for the year in advance, they might be allowed the benefits of the project without trouble to our authorities The first 2 miles of the canal line runs in that territory, and the land necessary (about 10 acres) might be bought outright The dam itself is in the territory of the British Government. The village of Pargaum will be submerged, and also about 1,000 acres of land The land, excepting one or two plots of ground, is of a stony nature, scarcely available for profitable cultivation, and a very small compensation is required by the villagers for their loss I have communicated with the Collector of Ahmednugger on the subject, and a Committee assembled to fix the amount, the result of which is, that the sum of Rs 21,811-10-0 is fixed for the houses, &c, and Rs 741-12 0 annual revenue

The percentages of revenue may be calculated as follows —

		Rs
Cost of construction,		3,54,252
Compensation,		21,812
	Total Rs,	3,76,064
Anticipated revenue,		67,890
Deduction for maintenance, at 3 Rs per cent. of cost of construction,		10,727
Giving a net of revenue of		57,163
	or Rs 15 20 per cent.	

Specification

The proposed tank is situated near the village of Bhatodee It has, under former rulers, been attempted evidently to make this the site of an immense sheet of water, but the project was not carried out owing to either want of engineering skill or of funds The present earthen dam is about 4,648 feet in length, and is faced, in a portion, by a masonry revetment, as shown in the plan, for a length of 1,960 feet It is now proposed to heighten the earthwork to a level of 73 feet above the lowest point in

that at least 57 cubic feet a second are available for irrigation, which, at 150 acres per cubic foot, gives 8,550 acres. Taking the rates of 12 months, 8 months, and 4 months' irrigation as Rs 9, 5, and 3 respectively (which are low rates), the resulting numbers of acres and amount of revenue are as follows —

			Rs
12 months,	acres	3,360, amount,	30,240
8 „	„	2,400 „	12,000
4 „	„	8,550 „	25,650
	Acres,	14,310	Rupees, 67,890

So much for the revenue.

I now come to speak about the dam. The old masonry dam is made of beautiful work, the tank side, coursed, and outside, uncoursed and rough, and well adapted for new work to be added on to it. It is of such an ancient date, that the chunam can scarcely be distinguished from the stone itself in regard to hardness and structure. According to instructions, I have left all of it without making any additions to it, except the filling in of a gap, as shown in the plan.

Rs 1-10-0 per 100 cubic feet have been taken for the earthwork, also Rs 8 for the pitching has been taken, as the débris of the old pitching may be worked up again with but little expense.

The site for the regulating sluice has been carefully selected. The form given to the "tower" I hope will meet with approval. Two pipes of 3 feet diameter are used, which, it is calculated, are amply sufficient for the whole of the water to be discharged.

The channel for egress of the waste water I have made with a breadth of 850 feet, according to instructions, and it will be quite ample to carry off the greatest flood.

The canal line has been taken with 1 and 2 feet fall in a mile in the plan. The first has been taken partly in order to give rather less cutting in some parts, and also to give a better fall to the distributing canals. In one place it will be seen that a deep cutting of 24 feet is made. This could not be avoided, owing to the great steepness of the river banks themselves, which forbade the idea of bringing the line to a position where the cutting would be more favorable. The total length of the canal is $4\frac{1}{2}$ miles, and the cost, including the bridge, Rs 55,726, which gives about Rs 12,000 a mile.

Six distributing sluices are to be constructed in the places which, during the progress of the work, may appear most fit

Owing to the difficulty of making agreements with the Government of the Assigned Districts, I have thought it advisable not to attempt to expressly irrigate any portion of the Nizam's Territory Should any of the inhabitants of Bhalooree, however, feel disposed to pay a water rate for the year in advance, they might be allowed the benefits of the project without trouble to our authorities The first 2 miles of the canal line runs in that territory, and the land necessary (about 10 acres) might be bought outright The dam itself is in the territory of the British Government. The village of Pargaum will be submerged, and also about 1,000 acres of land The land, excepting one or two plots of ground, is of a stony nature, scarcely available for profitable cultivation, and a very small compensation is required by the villagers for their loss I have communicated with the Collector of Ahmednuggur on the subject, and a Committee assembled to fix the amount, the result of which is, that the sum of Rs 21,811-10-0 is fixed for the houses, &c , and Rs 741-12 0 annual revenue

The percentages of revenue may be calculated as follows —

		Rs
Cost of construction,		3,54,252
Compensation,	..	21,812
	Total Rs., ...	3,76,064
Anticipated revenue,	.	67,890
Deduction for maintenance, at 3 Rs per cent of cost of construction,	.	10,727
Giving a net of revenue of	...	57,163
	or Rs 15 20 per cent.	

Specification.

The proposed tank is situated near the village of Bhatodee It has, under former rulers, been attempted evidently to make this the site of an immense sheet of water, but the project was not carried out owing to either want of engineering skill or of funds The present earthen dam is about 4,648 feet in length, and is faced, in a portion, by a masonry revetment, as shown in the plan, for a length of 1,960 feet It is now proposed to heighten the earthwork to a level of 73 feet above the lowest point in

the masonry, and thus get a sheet of water to irrigate about 14,310 acres

The dam consists partly of the old masonry untouched (except the filling in of a gap with new coursed rubbled masonry) and earthwork of dimensions given in the plan Description of old masonry is hammer-dressed coursed in chunam inside, and uncoursed rubble on the outside, the embankments along and at the ends of the masonry dam to be made in layers of 2 feet thick, watered and rammed The embankment on the tank side to be well pitched, and in the gap in the old embankment, a puddle wall to be run up with the new enbankment

The Canal to be 4 miles and 2,905 feet in length, to be divided into four sections, viz 1st, from 1st mile to the end of the 2nd mile, to be 11 feet broad at bottom and 4 feet deep, side slopes 1 to 1 with one foot fall per mile The 2nd, from the end of 2nd mile to that of $3\frac{1}{2}$ miles, to be 9 feet broad at bottom, 3 feet deep, side slopes $1\frac{1}{2}$ to 1, with one foot fall per mile The 3rd, from the end of the $3\frac{1}{2}$ miles to that of the 4th, to be $7\frac{1}{2}$ feet broad at bottom, 3 feet deep, sides slope $1\frac{1}{2}$ to 1, with 2 feet fall per mile The 4th, from the end of the 4th mile to the end of the canal, bottom breadth 6 feet, 3 feet deep, sides slope 1 to 1, with two feet fall per mile

The embankment to be raised in layers of 2 feet each, watered and rammed, and having the side slopes 2 to 1

The *Aqueduct* to consist of 6 arches of 12 feet span and $1\frac{1}{2}$ feet thick The foundation to be carried 3 feet deep, the description of masonry for foundation to be uncoursed rubble in chunam, that of superstructure to be of coursed rubble The wing walls to be carried into the bank of the nullah The embankment for approaches to be made in layers, watered and rammed

The *Escape* to consist of two openings of 4 × 4 feet, foundation of the escape to be uncoursed rubble masonry in chunam, and the superstructure to be of coursed rubble masonry in chunam, an apron to be made to the rear side, 4 feet in breadth and 1 foot deep

The *Breast wall* to be 60 feet in length, 3 feet in breadth, 3 feet in height in the centre, and 5 feet at the approaches. The foundation to be 2 feet deep.

Bridge, No 1 —The bridge to be constructed below the level of the ground as shown in the plan, foundation to be of uncoursed rubble masonry in chunam. Superstructure, of coursed rubble masonry in chunam

Bridge, No 2 —The foundation of uncoursed rubble masonry in chunam Superstructure to be coursed rubble masonry in chunam. The embankment to the approaches to be made in layers of 2 feet each, watered and rammed

Abstract of Estimate

	Rs
The dam,	2,00,174
Tower and tunnel,	17,216
Waste weir,	8,513
Canal,	44,441
Aqueduct of 6 arches,	4,488
Escape, of two openings,	788
Breast walls,	1,032
Bridge, No 1,	512
„ No 2,	1,007
Compensation to villagers of the village of Pargaum,	21,812
Grand total cost, Rs ,	2,99,983

No CLXXXV

PREPARATION OF ASPHALTE

Memorandum on the preparation of Asphalte for the flooring or roofing of buildings in India BY R C DOBBS, ESQ, *Executive Engineer, Bangalore*

Instructions for the application of asphalte —When the application is to a pavement or floor for foot traffic only, and the ground is perfectly solid, all that is required is to bring it to an even surface by hand-floating over it about an inch or an inch and a half of fine concrete If the ground is not solid, it must be made so by the removal of the soft and decayed parts, and then by ramming and filling up to the required level with *coarse concrete*, to be prepared as follows —

Take of clean, sharp gravel, free from earthly particles, rejecting all stones larger than a pigeon's egg,	7 parts,
Of fresh ground stone lime, .	1 „

mix them together in a dry state, and add just sufficient water to thoroughly moisten the whole Thus prepared it should be immediately thrown on the ground intended to receive it, and levelled to the depth required (varying from 3 to 6 inches) by a workman, who should be followed by another to ram it solid with a beater

The interstices seen between the stones of this concrete must be filled up with the least possible quantity of *fine concrete*, to be thus prepared —

Take of gravel, as before, rejecting all stones that will not pass through a sieve of 6 meshes to the square inch, .	6 parts,
Of very fine ground lime, ...	1 „

mix and moisten these ingredients as before, and then quickly and carefully hand-float them over the coarse concrete, to fill up the interstices and to make the surface perfectly true Inequalities of surfaces should be carefully avoided.

Where sharp clean gravel cannot be obtained, a foundation must be formed of broken stones, bricks or other hard substances

The concrete should be firm and solid, and it should be dry before the asphalte is applied. This should be more particularly attended to in covering roofs and arches, or in any work where the object is to prevent the percolation of water

The drier the concrete is, the better will be the work Where any blisters are discovered (and they should be carefully looked for) in the progress of the work, the places where they appear must be pricked, and after being touched with a trowel, nearly red hot, well rubbed over with a plaster's hand-float, for the purpose of closing them.

When the asphalte is to be laid on the floor of bath or other rooms where the foundation is solid, it will be sufficient to pick the surface, taking care that all inequalities are filled up with fine concrete as before described In bath rooms the concrete should be laid with the required inclination to prevent the lodgment of water All dust and sand to be carefully swept off before applying the asphalte

Directions for the use of the caldron —The caldron should be placed close to the work, where this is not practicable, the asphalte must be conveyed to the workmen in ladles or in small iron buckets, which should be heated for the purpose of preserving the asphalte longer in a state of fusion

In covering arches or roofs the caldrons must be hoisted to the top of them When the space occupied by the caldron only remains to be covered, it must be placed upon a part of the work already executed, to prevent that part being damaged by the heat, 3 inches of sand should be spread over it, and upon that a course of bricks for the caldron to rest upon

Fuel —The best description of fuel for heating the caldron, is common dry wood of any sort

How to fuse and prepare the asphalte.—The fire having been lighted in the caldron or under the iron pot, put into it from 100 to 250 lbs., (according to size of pot) of asphalte, broken into small pieces of not

more than $\frac{1}{2}$ lb each, mix the asphalte with a stirrer in such a way that the pieces at the bottom are constantly brought from the bottom to the surface When the whole quantity is thoroughly fused, sand or grit is to be added in the porportion of two parts sand to one of asphalte (to ensure exactness both asphalte and sand should be measured with the same basket or measure) The sand should be added gently and constantly stirred for the purpose of keeping the contents of the boiler properly mixed, and to prevent their becoming burnt and clinkered to the sides and bottom of the boiler When fit for use, the compost will emit jets of light smoke and freely drop from the stirrer, it should then be raised as rapidly as possible to prevent its becoming over-burnt

Directions for applying the compost —Having selected the gauges of the required thickness, place one with weights bearing on its outer edge, parallel to one of the sides to be covered and at a distance of about 3 feet, this will form the width of the several layers of pavement or flooring to be covered In this space the spreader kneels, and, as soon as the compost is poured down, it is to be spread with a trowel of the description hereafter specified To facilitate this work, an ordinary floating rule or piece of straight, hard, wood, about $3\frac{1}{2}$ feet in length, may be used to level the compost to the thickness of the gauge, and any unevenness in the surface may be easily corrected by the trowel or hand-float

Before the compost becomes hard, a small quantity of very fine sand should be sifted over it, and well rubbed into it with the hand-float

The contents of each caldron should be sufficient to cover one layer, and it should be poured all along the space to be covered If a considerable quantity remain, the gauge may be widened, but if only a small quantity, it should be put back into the caldron and boiled over again with the next supply

When the space to be covered is bounded by a wall, the required thickness may be obtained by fixing a thin strip of wood with a straight edge to the side of the wall at the breadth or thickness of gauge above the floor

When the first layer is finished the adjoining space should be covered at a later period [The object of leaving alternate vacant spaces is, that the workmen employed in rubbing may not have occasion to kneel upon any part of the asphalte until cool, nor should the gauge be re-

moved until the asphalte has become set] Adjoining this vacant space, two gauges are then to be laid down at the same distance apart and weighted, as before-mentioned The space between the gauges must then be covered with the compost, and rubbed in the manner before described In about half an hour, the compost will have become quite firm, when the gauges should be carefully removed The sides of gauges should be oiled to prevent their sticking

The following important points should be attended to, for the purpose of making the joints of the several layers perfect

1st Any dust should be brushed from the edge of the layers

2nd The compost should be poured and worked with much force close against them, &c

3rd The edge or joint to be warmed with a heated trowel, and, after a little fine sand has been sifted over it, to be well rubbed with the hand-float

When the surface to be covered is the extrados of an arch, all inequalities should be filled up, and while the mortar is moist, it should be scored all over in parallel lines from 3 to 4 inches apart These lines should be at right angles to the axis of the bridge, the object being to make a surface sufficiently rough to prevent the layers of asphalte slipping or sliding

Description of materials and how to prepare them —The day previous to applying the asphalte, the materials should be prepared and stored close to the work

The asphalte to be broken into small pieces of not more than ½ lb each

Sand should be clean, sharp and coarse, all pebbles and earthy particles to be carefully removed, and the fine sand to be thoroughly separated by sifting

The fine sand thus obtained to be again sifted, to remove any coarse particles and used for dusting over the compost, as before described

Labor —There are two classes of men employed in asphalte works—1st, Those called spreaders, who should be by trade plasterers or bricklayers, and whose business it is to lay the asphalt, and 2nd, The caldron men, or ordinary coolies, their duties are to prepare the materials and tend the fire

For small works two caldrons would be sufficient, and care should be taken so to arrange them, that by the time one is emptied, the other

may be ready, this may be effected by lighting them at intervals of a quarter of an hour For large works there should be six or more caldrons or pots

When two caldrons are used, there should be two spreaders and five coolies to tend the fire and keep the contents of the boiler constantly stirred When there are three or more caldrons, the numbers should be increased proportionately, but, as a general rule, three spreaders will be sufficient for any work

Utensils —A common iron boiler, about 2 feet in diameter, and 4 feet 6 inches high, is the best for all ordinary works

The handles are required to admit of a piece of wood being passed through them, so that the boiler or caldron may be conveyed to the room or place to be covered

The *Stirrer* may be any piece of pliable wood of sufficient length and strength

Gauges to be of hard wood about 3 inches broad, and of the thickness required

Trowels should be similar to common mason's trowel, but $\frac{3}{8}$ths of an inch thick, and handles one foot long, made to slip off and on

General remarks —When fusing asphalte in a cold climate, it is necessary to mix with it a small quantity of mineral tar, but it has been found by experiment that this is not required in a tropical climate It has also been ascertained, that the admixture of sand or grit in the manner previously described, is preferable to the English method of beating the grit into the asphalte, before it has set or become hard

When applying the asphalte to the floor of a room, care should be taken to keep all doors and windows open to allow of the escape of the smoke. After the asphalte or compost has been laid, it should be carefully and steadily rubbed with a hand-float till the surface is perfectly even and true

For the flooring of rooms or tops of arches, a layer $\frac{3}{4}$ths of an inch thick will be sufficient, but for pavements, where there is much foot traffic, the thickness should be increased from an inch to an inch and a half.

Weight of Material

One superficial foot of pure asphalte, coarse quality $\frac{3}{4}$ an inch thick, weighs, ...	6 lbs. $2\frac{1}{2}$ ozs.
One " fine quality, weighs, .	6 " $8\frac{3}{4}$ "

One square (100 superficial feet) covered with compost, in the proportion of one part asphalte to two of sand, ¾ths of an inch thick, requires 375 lbs of asphalte

One ditto, 1 inch thick, 500 lbs

Details of cost for one square ¾ inch thick

	RS	AS	P
375 lbs of asphalte, @ 94 Rs per ton,	15	11	9
Sand, inclusive of cost of sifting,	0	4	0
Fuel,	2	0	0
Labor,	1	2	0
Total of square, Rs,* ...	19	1	9

Particulars of labor

2 Bricklayers, @ 10 annas each,	1	4	0
5 Coolies @ 3 ditto,	0	15	0
Contingencies, ..	0	1	0
Total, Rs,	2	4	0

will do 2 squares per day

Details of cost for one square ¾-inch thick, in the proportion of one part asphalte to one of sand

450 lbs of asphalte, @ 94 Rs per ton, ...	18	14	2
Sand, inclusive of cost of sifting,	0	3	0
Fuel,	2	0	0
Labor,	1	2	0
Total for one square, Rs,*	22	3	2

Recipe and analysis of expenditure for laying down asphalte as practised on the Madras Railway.—The asphalte is prepared by melting in iron-pots, sand is mixed with it in the proportion of 4 of asphalte to 3 of sand, poured on the floor (which has been previously levelled with concrete) in 2 coats of ⅜ths of inch thick each, the first coat being allowed to cool before laying on the other, this is smoothed over with a wooden

* These rates are calculated to cover the cost of carriage from Bangalore to any part of the Mysore territory within a radius, but not that of utensils and tools.

float, a little oil being applied to it to prevent sticking, the surface then is covered with fine sand which is rubbed gently over it to clean it and is afterwards swept off, should any cracks or blisters appear, they may be removed with a hot iron trowel

Cost per square, or 100 superficial feet

		RS	A	P
Asphalte, @ 50 Rs per ton,		20	6	5
Sand, 585 lbs, @ Rs 3-8 per 15,000 lbs,		0	2	7
Labor,		0	10	0
	Total,	21	3	0

Particulars of labor

3 Bricklayers, @ 6 annas,		1	2	0
4 Coolies, @ 3 ditto,		0	12	0
2 Women, @ 1-7 ditto,		0	3	2
2 Boys, @ 1-6 ditto,		0	3	0
	Total,	2	4	2

will do four squares as above Per square, annas 10

Additional remarks by the Executive Engineer —The use of oil is objectionable, as native workman are inclined to use so much that the surface of the asphalte is softened

The proportion of sand used by the Madras Railway Department is not sufficient to render the compost capable of resisting the effects of the sun

The proportion of sand and asphalte previously specified [viz, 1 of asphalte to 2 of sand] has been found, by experiment, to be the best for pavements or verandahs, but when the floor is protected, the materials may be used in equal parts, as inexperienced workmen will not be able to spread the compost properly when the proportion of sand exceeds that of the asphalte

The use of pots of the description shown, will obviate the necessity for using ladles or iron buckets.

Extract from a pamphlet of Instructions for the use and application of Pyrmont Seyssel Asphalte, "Claridge's Patent"

"*Fuel* —The best description of fuel for heating the caldron is peat and oak wood Coal is objectionable on account of the smoke it creates.

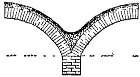
Coke should never be used, it is injurious to the material and destructive to the caldron.

" *How to fuse the asphalte* —The fire having been lighted in the caldron, put into the boiler 2 lbs of mineral tar, to which add 56 lbs of asphalte broken into pieces of not more than 1 lb each Mix the asphalte and tar together with the stirrer, till the former becomes soft, and then place the lid on the caldron, keeping up a good fire In a quarter of an hour, repeat the stirring and add 56 lbs more asphalte in similar sized pieces, distributed over the surface of that in the caldron. Again cover the caldron for 10 minutes, after which keep the contents constantly stirred, adding, by degrees, asphalte in the proportion of 112 lbs to 1 lb of tar, until the caldron is full and the whole is thoroughly melted When fit for use the asphalte will emit jets of light smoke and freely drop from the stirrer Should it be wished to convert fine asphalte into coarse, 25 lbs of grit (clean and free from dust and passed through a No 10 sieve is to be added to each 112 lbs of the former, in which case the proportion of tar will be 3½ lbs instead of 1 lb for every cwt) In India and other tropical climates, where the asphalte is more readily fused, an excess of tar should be particularly avoided

" When the surface is intended to be gritted, a workman should immediately follow the spreader and evenly distribute from a sieve a clean grit of the size mentioned in the table annexed, according to the nature of the work

" The grit will, if heated, be found to unite more firmly to the asphalte, which can readily be done, in small works, upon the lid of the caldron. A double handed beater is to be used, with which the grit should be stamped perpendicularly, and with rapidity and much force into the surface of the asphalte

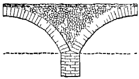
" A small beater is employed for beating the grit into the asphalte in corners, or for making good the joints round a sink, drain, trap, &c."



" *Arches* —There are two modes of covering arches —

1st By merely cutting away any unevenness on the surface of the brick work and concreting the angle of the spandril, and fine concreting over the crowns of them

"2nd. By filling in the spandrils with coarse and fine concrete



level with the crowns of the arches, in order that it may answer the purpose of a foot pavement, as well as an impervious covering to them

"When either of the two systems of covering arches is adopted, care should be taken to provide for drainage"

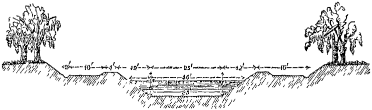
R C D.

No CLXXXVI

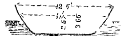
NOTE ON NAVIGATION CANALS

Memorandum on the dimensions proposed for Channels and Masonry works of Navigation Canals in Upper India By MAJOR H. A. BROWNLOW, R E, *Superintending Engineer.*

Proposed section of Channel.



THE midship section of wooden boats in general use on these canals is given.



Length, 45 feet.
Top width, 12 5 feet
Bottom width, 8 0 feet — midship section.

Draught 2 5 feet, when laden with 450 to 500 maunds, the usual burthen

Rankine gives as dimensions and proportion of channel, required to prevent any material increase of resistance to motion of boat, beyond what it would encounter in open water

Least breadth at bottom = 2 × greatest breadth of boat.

Least depth of water = 1 5 feet + greatest draught of boat

Least area of water section = 6 × greatest midship section of boat.

Side slopes not less than 1 in 1·5.

The midship section, to water line, of the wooden boat, of which the dimensions are given above, may be taken as 25 superficial feet

Area of water section of proposed channel = 162 5 superficial feet

Depth of proposed channel = 2 5 + usual draught.

Bottom width = 2 × greatest breadth

Side slopes of proposed channel, 1 in 1 5

Mr Kelly (whose opinion is most deserving of consideration) would prefer side slopes of 1 in 2, in order to admit of gravel or pitching being laid along the line of wash, for protection of slopes Side slopes have been made 1 in 1 5, however, with the view of economising excavation and ground occupied by channel

Towing paths —Towing-paths to be provided on each bank To be 3 feet above surface of water except in very deep digging, where, to economise excavation, they should run 4 feet above water surface To be 10 feet wide in the clear, with a slope of 1 in 20 to outside An edging 4 feet wide at bottom, 2 feet wide at top, and 1 foot high, to run along crest of side slope of channel, and a shallow drain 2 feet wide, and 6 inches to 8 inches deep along exterior edge of towing-path, when there is a spoil bank.

Spoil Bank and Plantations —Spoil to be thrown with an interior slope of 1 in 1 Exterior to be sloped off like a glacis, and to be planted with trees. Mr Kelly strongly advocates establishment of plantations on both banks of still water channels, along their whole lengths, as tending to check their obstruction by drift of sand, dust, &c The proposal is a most excellent one, and is strongly recommended for adoption, where the value of land that would be occupied by them is not exceptionally high

Embankments and Puddling in Sandy Soil —All embankments to be formed and rammed in thin layers Where the channel runs through porous sandy soil, bed and banks to be covered with a thin coating of puddle. This might be effected more cheaply after the opening of channel by boating pulverised clay to the requisite points and strewing it over the surface of the water

Waterway and Headway of Bridges —Waterway of bridges 16 × 5 feet, clear headway for boats, 16 × 10 feet, clear headway for towing path on each side, 6 × 5 feet, $5\frac{1}{2} \times 4\frac{1}{2}$ feet (height) being required for passage of a pair of yoked bullocks. Section of bridge to be as shown in *Fig* 1, *Plate* XXI.

NAVIGATION CANALS

Fig. 1.

Dimensions of Arch for Still Water Channel

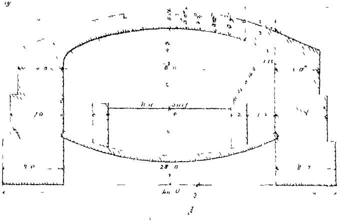
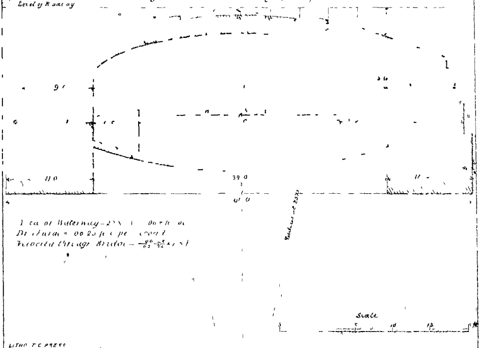


Fig. 2.

Dimensions of Arch with Velocity of 2.5 feet in Channel



LITHO. T.C. PRESS

Locks.—Lock chambers to be 100 feet by 16 feet in the clear, and to be on general plan given in Plate XXIII, Atlas to Col Cautley's Report on Ganges Canal, with the substitution of a second lock chamber for the side chamber constructed in the Ganges Canal locks.

Stop Dams.—Channel to be divided by stop dams into reaches of two, or at the outside, three, miles in length, so as to isolate a breach, or any point where drainage may have broken in, also to enable any portion to be laid dry in case of repairs being required These stop dams to be formed of 2 pairs of lock gates, shutting in opposite directions Such a dam to be constructed also at junction with main canal to keep out silt, and guard against fluctuations of level

Under Sluices.—Each reach of the channel between any two stop dams to be provided with an escape outlet, by which it may be wholly emptied of water for clearance or repairs if necessary

Waste Weirs.—Also with a waste weir, to provide for discharge of any drainage that may accidently find its way into the channel

Drainage.—Arrangements to be made, however, for diverting, or passing under the channel, all drainage that may intersect the line.

CHANNEL WITH FLOW OF 2 5 FEET PER SECOND.—Where possible, however, the navigation channels to be designed so as to secure a velocity in them of $2\frac{1}{2}$ feet per second

Section of earthen channel to be as in page 161 *Calculation of* D *and* S. —Then assuming section given above, as minimum allowable (for reasons given), we have—Discharge of channel $= A \times V = (32\ 5 \times 5) \times 2\ 5$ $= 406\ 25$ cubic feet per second, $S = \frac{90^2 \times R}{V^2} = 1296\ R = 1296 \times 3{\cdot}8 = 4924\ 8$, giving a fall of 13 inches per mile, very nearly.

Waterway and Headway of Bridges.—16 feet long by 10 feet clear headway, to be allowed for boats, with a couple of towing-paths, clear headway of each 6 feet × 5 feet *Fig* 2, *Plate* XXI

Towing-paths.—Towing-paths to be as laid down above for still water channels

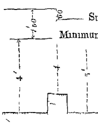
Locks.—Locks to be double, with a chamber in centre, similar to the side chamber in Ganges Canal locks (*see* Atlas, Plate XXIII)

Points of departure from, and junction with, Main Channel.—Channel to be provided with regulating chambers, in form of locks, with level floorings, at points of departure from, and junction with, main channel. The surface level of canal is liable to fluctuations within

the limits of $2\frac{1}{2}$ feet, and supposing surface level in navigation channel fixed about one foot above level of minimum supply (which is exceptional, and short in duration) the navigation channel would during periods of minimum supply be discharging 282 feet per second, with a depth of 4 feet, and a mean velocity of $2\frac{1}{4}$ feet per second But when the canal supply was at its highest, the navigation channel would be discharging 677 cubic feet, with a depth of $6\frac{1}{3}$ feet and a mean velocity of $2\frac{1}{4}$ feet per second This increase in depth would be very inconvenient, perhaps dangerous, and it would add considerably to the expense of bridges and earthwork, along the whole line of navigation channel, to provide properly for it. Again, the surface level of the navigation channel, at point of junction with canal, must be fixed on the level of full supply in the latter, otherwise a rise in the main channel would throw a back water up the navigation channel to an extent proportionate to its height, and silting up at the junction would inevitably follow the checking of velocity Regulating chambers, at the head and tail of navigation channels, seem therefore absolutely necessary.

These chambers might be made, as suggested before, in the form of a lock chamber, 100 feet long by 16 feet wide in the clear At the head of the nagivation cut, with a low supply, or average supply, in the canal, both gates of the chamber would be kept open When the supply in the main channel rose to an inconvenient height, both gates would be closed, and the navigation cut would then be fed through a side inlet

The flooring of this inlet would be built about a foot above the canal bed, so as to keep out the water most highly charged with silt It would have to consist of about four bays of 6 feet width each, the bays being closed by sleepers dropped into grooves as occasion required, thus, at the tail of navigation cut, when the water in canal fell so much below the full supply level as to cause an inconvenient increase of velocity in the channel, the lock gates would be closed and the velocity would be duly regulated by increasing or reducing the discharge through a side chamber.



$$D = c_d \, l \sqrt{2gd_1} \, (d_2 + \tfrac{2}{3} d_1)$$

$$D = 406\ 25\ C_d = 0\ 628$$

$$d_1 = 0\ 60 \quad d_2 = 4\ 0$$

$$l = 24 \text{ feet, very nearly}$$

H. A. B.

No CLXXXVII

NOTES ON THE MISSISSIPPI REPORT

Report on the Physics and Hydraulics of the Mississippi river By CAPTAIN A A HUMPHREYS *and* LIEUT M L ABBOT, *Corps of Topographical Engineers, U S Army* *Philadelphia*, 1861.

As the "Report on the Mississippi" by Messrs. Humphreys and Abbot may not be accessible to many readers of the "Roorkee Professional Papers," a few notes in explanation of the important conclusions they arrived at, with regard to the distribution of the velocities from the surface to the bottom of this river, may prove of some utility The report is a very elaborate and exhaustive one, and a great part of it is taken up with a description of the basins of the Mississippi itself, and of its numerous affluents, and of the measures proposed for the protection of the extensive tracts of country which are liable to be more or less submerged by floods, together with an account of the Delta proper and of the influence of the sea on the condition of the various outlets to the Gulf of Mexico Information on these points can best be obtained by a reference to the report itself, which, though voluminous, could not be epitomized into small compass, except by the omission of much valuable matter I do not, therefore, propose to follow Messrs. Humphreys and Abbot through the whole report, or even to describe the nature of the works which they recommend for the protection of the alluvial lands against inundation I propose to confine my remarks to an account of the results of the numerous observations which the authors had to make, to enable them to arrive at an accurate knowledge of the discharge of the river at different stages, and which have led to certain con-

clusions, which, if true for the Mississippi, may be made more or less applicable to other rivers, or which, at all events, possess a general interest apart from hydrographical or geographical questions relating to the Mississippi alone

The authors, after testing all the formulæ they could find in works on hydraulics, came to the conclusion that none of them were to be trusted, and, in consideration of the importance attaching to a correct treatment of the Mississippi, and of the serious consequences which any incorrect assumptions might lead to, they felt themselves bound to reject all theory which was not based on observations conducted on the Mississippi itself, and which could not stand the severest tests, in support of its soundness, that could be thought of They had thus to go over the ground traversed by Du Buat, Prony, Eytelwein and others, afresh, but with this difference, that whereas the investigations of these authors were for the most part confined to experiments on small channels, theirs were carried out on a noble river, half a mile wide, and from 50 to 100 feet, or more, deep

The most important point to be determined was the mean velocity of the river Engineers usually either adopt Du Buat's or Prony's formula, which gives the velocity in terms of the fall of surface and the hydraulic mean depth, or they take a certain number of observations of the surface velocity, at intervals across the stream, and assume the mean velocity to be about $\frac{9}{10}$ths the average surface velocity But, as above explained, the first method was rejected, and, as regards the second, it was found that the mean velocity bore no fixed proportion to the maximum or mean surface velocity It is obvious, therefore, that unless some formula could be obtained, which would allow for the variations of velocity from surface to bottom, the mean velocity of the river could only be ascertained from a great number of observations taken at nearly uniform intervals throughout the transverse section Such an undertaking, though indisputably the most certain procedure, would have been extremely laborious and difficult, in consequence of the great size and velocity of the stream, and of the number of different stations and stages of the river at each, to which the observations would have had to be extended It, therefore, was an object of great importance to arrive at some formula which should furnish the means of ascertaining the mean velocity from a limited number of observations, and with this view, the authors proceeded in the first instance to institute a series of experiments for the purpose of determining the law governing

the change of velocity from the surface to the bottom of the river, in a vertical plane parallel to the direction of the current

These observations were conducted in 1851, at Carrolton and Baton Rouge, from boats anchored at different distances from the banks, and a number of isolated observations were made at other points To counteract as far as possible the effect of changes of velocity while the observations were in progress, the order of observing at different depths was constantly varied It is needless to describe the mechanical part of the operation, which was attended with considerable difficulties It is explained, however, in full detail by the authors, and, indeed, in all matters on which they treat, they place all the information acquired by themselves before the reader, and give him the opportunity of verifying their conclusions, or of correcting them, should they be proved to be unsound Evidently, the greatest pains have been taken throughout, both to ensure accuracy in the observations and to record them in a perfectly faithful manner, without any attempt to slur over discrepancies which may appear in the results

The velocities were observed at different stages of the river, ranging from depths of 55 to 110 feet They were embodied into six groups, according to the depths, and the means for each group were then taken The results are shown in Tables I to VI, appended to these remarks I have thought it advisable to place them before the reader, for it is only by examining them for himself, that he can form an opinion of the soundness of the theory about to be explained

The mean velocities at the different observed depths below the surface were then plotted the depths as ordinates and the corresponding mean velocities as abscissæ,—an operation which the reader is recommended to repeat for himself, and a series of curved lines were thus obtained, which, according to the authors, at once indicate the existence of a law, although the discrepancies are too great to permit of any algebraic expression for it It appeared however that "the velocity varies but little at different depths, that it first increases and then decreases, as the depth is increased, that the point of maximum velocity is found at a very variable depth below the surface, and that the degree of curvature varies with the stage of the river"

A further combination was therefore made to eliminate the effect of disturbing causes. This was done by combining all the observations for fractional parts of the depths, instead of for the absolute depths below the

surface "The mean curves were plotted on a scale so distorted that thousandths of a foot of velocity were readily distinguished The entire depth was divided into ten equal parts Horizontal lines were drawn, and the velocities at their points of cutting the curves noted The numbers were the most correct interpolations that could be made for the velocity at each *tenth* of depth, and they were next combined in the ratio of the number of observations at each point of the original curves of observation "

I do not follow the authors in their investigation into the nature of the curve thus obtained Suffice it to say, that it was parabolic, and that the parameter was 1 2621 D^2, D being the depth of the bed below the surface The equation to a parabola is $y^2 = mx$, where m is the parameter,

$$\text{hence } y^2 = 1\ 2621\ D^2 x$$

$$\text{or } x = \quad 7922\ \frac{y^2}{D^2}$$

The maximum velocity, which was at nearly one-third the depth, was 3 2611 feet per second

The velocity at any point situated at the distance y from the axis of the curve was, therefore,

$$3\ 2621 - 7922\ \frac{y^2}{D^2}$$

The following table exhibits the results obtained from the above equation compared with those of the observations

Depth of float below the surface	Velocity by observation	Velocity by above equation	Difference	Remarks
Surface .	3 1950	3 1901	+ 0 0049	Grand mean of all observations taken from anchored boats, combined in ratio of number of observations at each determined point They were taken at Carrolton and Baton Rouge in 1851 Each point is fixed by 222 observations Mean maximum velocity, which is 0 297 D below the surface, is 3 2611 feet Mean depth is 82 feet Mean wind is down, force 0 2 Mean velocity of river is 3 3814 feet per second
0 1 D	3 2299	3 2293	+ 0 0006	
0 2 D	2 2532	3 2525	+ 0 0007	
0 3 D	3 2611	3 2600	+ 0 0011	
0 4 D	3 2516	3 2525	— 0 0009	
0 5 D	3 2282	3 2274	+ 0 0008	
0 6 D	3 1807	3 1873	— 0 0066	
0 7 D	3 1266	3 1313	— 0 0047	
0 8 D	3 0594	3 0596	— 0 0002	
0 9 D	2 9759	2 9719	+ 0 0040	
Bottom,		2 8685		
Sum of common points,	31 7616	31 7619	0 0245	
Mean of common points,	3 1762	3 1762	0 0024	

The authors consequently claim that experiment demonstrates that the velocities at different depths below the surface, in a vertical plane, vary as the abscissæ of a parabola, whose axis is parallel to the water surface, also that the axis of the curve may be considerably below the surface.

The next step was to ascertain whether the parabola retained an unchanging parameter and a uniform position of axis. A very laborious investigation was followed up, by combining separately all high water and low water curves, reduced to tenths of depths, each curve having a weight proportional to the number of observations at each point From this it was ascertained that the high water curve was parabolic in form with the axis 0 350 of the depth below the surface, and that the mean low water curve, though it exhibited greater irregularities, was also parabolic, with its axis 0 150 of the depth below the surface

The parameters of these curves were compared with that of the grand mean curve above described, but the result was unsatisfactory. It was found impossible to deduce sufficient proof to establish the existence of any mathematical law connecting them together.

"Baffled by the curves of sub-surface velocities themselves, a clue to the law was to be sought for elsewhere It was reasoned, since the force of these curves depends upon the general law of transmission of resistance to separation through the fluid, that the same law must govern the form of the curve of velocities from one bank to the other in a horizontal plane Hence the desired clue might be found by a study of the curves of surface velocities, which were well determined both at Columbus and Vicksburg This subject, therefore, was examined at this stage of the discussion of sub-surface velocities"

The authors proceeded to arrange the observations of the velocities in a horizontal plane at the depth of 5 feet below the surface, and to plot the results on curves in the same manner as was done for the velocities on vertical planes The observations were made at Columbus, where the section presented unusually small irregularities, at intervals of 200 feet across the channel, the width being about 2,000 feet, and eight groups were prepared, according to each even foot of the approximate mean velocity of the river, and plotted A grand mean curve of all the observations was formed by combining the eight mean curves.

The result was found to be a curve differing but slightly from a parabola, whose parameter was 117 18 W, W being the width of the river,

hence

$$y^2 = 117\ 18\ \mathrm{W}x$$

$$\text{and } x = \frac{y^2}{117\ 18\ \mathrm{W}}$$

The parameter of the curve thus obtained was then compared with those of the eight mean curves above-mentioned, and it was found after a careful analysis that the parameters were in the inverse ratio of the square roots of the corresponding mean velocities of the river The formula thus obtained was tested by its application to six other sets of observations at Vicksburg and was found to correspond with them very closely

The velocities obtained by observation and the formula are given in the report for each group,* but it is considered unnecessary to quote them, as the formula is to be ultimately tested by other means

The relation of the parameters of the curves of the velocities on the horizontal planes to the corresponding mean velocities of the river having been established, it was inferred that a similar relation held good for the velocities in the vertical planes. It was assumed to hold good, and it then remained to test it by reference to the observations

It has already been shown that the formula for the velocity curve of the grand mean of all the sub-surface velocities at Carrolton is $y^2 = 1\ 2621\ \mathrm{D}^2x$ where D is the total depth of the stream, y the depth from the axis of the curve, and $1\ 2621\ \mathrm{D}^2$ the parameter of the curve The mean velocity of the river was 3 3814 feet per second

Calling this v_1, and $1\ 2621\ \mathrm{D}^2$, m_1, we have for the parameter, m, of any other vertical curve corresponding to a mean velocity of the river equal to v, by the above law—

$$\sqrt{v} : \sqrt{v_1} :: m_1 : m = m_1 \sqrt{\frac{v_1}{v}}$$

$$= 1\ 2621\ \mathrm{D}^2 \sqrt{\frac{3\ 3814}{v}}$$

$$= \frac{2\ 3212\ \mathrm{D}^2}{v^{\frac{1}{2}}}$$

$$= \frac{1}{4308\ v^{\frac{1}{2}}}\ \mathrm{D}^2$$

$$= \frac{1}{(1856\ v)^{\frac{1}{2}}}\ \mathrm{D}^2$$

hence the equation to the curve of any sub-surface velocities in the vertical plane parallel to the current,

* Pages, 240, 242

$$y^2 = \frac{1}{(1856\, v)^{\frac{1}{2}}} D^2 x$$

$$x = (1856\, v)^{\frac{1}{2}} \frac{y^2}{D^2}$$

The velocity V at any point in the vertical curve, is found by subtracting x from the maximum velocity or that at the axis of the parabola, which we may term V_{d_1}, d_1 being the depth of the axis below the surface, y the depth above or below the axis of the point whose velocity is V. Representing by d the depth of this point below the surface, and d_1 as above, $y = d - d_1$, hence the formula becomes

$$V = V_{d_1} - (1856\, v)^{\frac{1}{2}} \left(\frac{d - d_1}{D}\right)^2$$

"This general formula is now to be tested as rigidly as possible by all the observations taken upon the survey. Besides the measurements from anchored boats, some additional data were collected, which though less exact in character, and therefore not admitted into the grand mean curve, are for that very reason especially valuable for the purpose, the constants of the formula being deduced independently of them. Agreement with such independent observations furnishes the highest proof of general applicability."

These additional data were observations on Bayou Plaquemine, where the cross section was of semi-elliptical form and quite regular, and where the depth for 150 feet near the middle of the Bayou was 27 feet, upon Bayou la Fourche under similar conditions, and upon the Mississippi at Columbus and Carrolton.

The result is shown in Tables VII. to X., and the co-incidence of the velocities obtained by observation and those elicited by the formula is very remarkable. The wonderful patience and ingenuity with which such results have been obtained cannot fail to excite the warmest admiration on the mind of every reader of Messrs. Humphry and Abbot's remarkable work.

"The weight of evidence in favor of the truth of the formula, and of the accuracy of the reasoning by which it has been deduced, is thought to be irresistible. When it is remembered that the forms of all the curves are fixed by one and the same equation, it must be admitted that so close an accordance with observations in localities and circumstances so different cannot be accidental."

"That the numerical co-efficient of $v^{\frac{1}{2}}$ should remain constant for so great changes in cross section was a matter of surprise, and the question

rose whether, for still smaller streams, it might not vary. Boileau's admirable observations on his wooden canals afforded a means of testing the matter As stated in the last chapter, Captain Boileau* considers his observations to indicate that the vertical curve below the point of maximum velocity is a parabola whose axis is at the surface, while the curve above the point of maximum velocity follows no discovered law The first set of experiments was made in a wooden canal or trough about 2 feet wide and 1 foot deep The observations near and below the point of maximum velocity were made partly with a new kind of hydrometric tube and partly with a current meter Above the vicinity of the point of maximum velocity, Boileau depended on floats which were observed only at the surface, thus leaving a relatively wide gap in the curve undetermined by measurement Now, it is evident that the difference between the surface velocity and that near the point of maximum must be affected by any error in the constants of the formula for computing the velocity from the tube and current-meter observations, and also by the retarding effect of the side resistances, if the floats deviated ever so slightly from the exact plane of the rest of the observations If the surface velocity was diminished by these causes of error to an amount equal to 0 077 of a foot per second, the entire curve agrees very well with a parabola whose vertex is, at the point of maximum velocity, 0 178 of the depth below the surface. Boileau's second series of experiments, made when the depth was reduced to 0 67 of a foot, fully confirms this opinion, as this curve is evidently one and the same parabola both above and below the point of maximum velocity, which is about 0 237 of the depth below the surface The two lower observations should probably be rejected, as they differ enough from the law of the others to suggest some anomalous influence of the bottom upon the current-meter The following table exhibits a comparison between these curves of observation and the parabolas given by the formula—

$$V = 2\ 8254 - 1\ 5206\left(\frac{d - 0\ 2034}{1\ 1418}\right)^2$$

$$V = 2\ 0079 - 1\ 2683\left(\frac{d - 0\ 16}{0\ 676}\right)^2$$

The axes are placed 0 178 and 0 237 of the depth below the surface, respectively, and the parabolas adjusted so that the mean of all the observations shall determine the mean of the corresponding points of the parabolas, disregarding, in the first case, the observation at the surface, and, in

* Traité de la Mesure des Eaux Courantes, 1884

the second, the two observations nearest the bottom The means of course include these observations

Sub-surface velocity curves from Captain Boileau's experiments.

FIRST EXPERIMENT				SECOND EXPERIMENT			
Depth	Observed velocity	Computed velocity	Difference	Depth	Observed velocity	Computed velocity	Difference
Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
0 0000	2 7002	2 7771	− 0 0769	0 000	1 9420	1 9368	+ 0 0052
0 1706	2 8544	2 8241	+ 0 0303	0 045	1 9680	1 9713	− 0 0033
0 2034	2 8577	2 8254	+ 0 0323	0 078	1 9810	1 9892	− 0 0082
0 2362	2 8544	2 8241	+ 0 0303	0 111	2 0010	2 0009	+ 0 0031
0 2690	2 8478	2 8204	+ 0 0274	0 144	2 0170	2 0068	+ 0 0102
0 3016	2 8380	2 8142	+ 0 0238	0 177	2 0170	2 0070	+ 0 0100
0 3346	2 8281	2 8053	+ 0 0228	0 200	2 0040	2 0034	+ 0 0006
0 4659	2 7527	2 7432	+ 0 0095	0 229	1 9880	1 9957	− 0 0077
0 5653	2 6411	2 6726	− 0 0315	0 262	1 9680	1 9802	− 0 0122
0 6299	2 5624	2 6132	− 0 0408	0 328	1 9120	1 9295	− 0 0175
0 7940	2 3590	2 4186	− 0 0596	0 492	1 7250	1 7059	+ 0 0191
0 8924	2 2243	2 2727	− 0 0484	0 557	1 6660	1 5705	+ 0 0955
0 9580	2 1359	2 1612	− 0 0253	0 623	1 5370	1 4133	+ 0 1237
1 0286	2 0374	2 0408	− 0 0034				
1 0893	1 9423	1 9100	+ 0 0323				
Sum,	38 4457	38 5229	0 4946	Sum,	24 7290	24 5105	0 3163
Mean,	2 5630	2 5682	0 0330	Mean,	1 9022	1 8854	0 0243

"The columns of differences, it is considered, justify the assumption that the law, already proved to exist in the Mississippi river, holds good in this little experimental canal If so, the co-efficient of $v^{\frac{1}{2}}$ in the parameter equation for a very small stream at once results Boileau does not give the mean velocity of the canal, but, since the observations were in the thread of the current, it may be determined with approximate accuracy by taking 0 8 of that observed at the surface This gives 2 1 and 1 5 feet for the mean velocity corresponding to the first and second series of experiments respectively Hence, designating by $b^{\frac{1}{2}}$ the co-efficient of the square root of the mean velocity, the following values of b result —

$$b = \frac{(1\ 5206)^2}{2\ 1} = 1\ 10$$

$$b = \frac{(1\ 2688)^2}{1\ 5} = 1\ 07$$

"These results, although rendered somewhat uncertain by the necessity

of approximating to the mean velocity, indicate a material change from 0.1856, the value of b already found for large rivers.

"The law of this change was considered an important object for investigation, but the existing data were insufficient, until, when studying the effect of change in slope upon discharge, in the autumn of 1859, it became highly desirable to test certain formulæ by actual observations upon a small stream. A feeder of the Chesapeake and Ohio Canal at the Little Falls of the Potomac, near George town, D. C., was selected, and incidentally another value of b was determined. The details of these experiments, so far as they relate to sub-surface velocities, will now be given before finishing the discussion of b.

"The observations were made by Lieutenant Abbot, on December 2nd, 1859, a calm and pleasant day. The clear water-way of the feeder, at the point selected, was 17 feet in width and 7.1 feet in depth, with a nearly rectangular masonry cross-section. The total width of the feeder was 23 feet; but in this vicinity one bank had partially caved in, thus obstructing the channel and more or less disturbing the water for about 6 feet from one edge. Throughout the remaining 17 feet, the current flowed with uncommon regularity from surface to bottom, thus affording an advantageous locality for the experiments. Every care was taken to obviate errors of observation. An examination of many published experiments had led to the belief that the subject, sufficiently difficult in itself, had been greatly complicated by the use of instruments whose intricate machinery introduced so many errors as to conceal the true form of the curve. Oftentimes different instruments had been used at different depths, almost necessarily introducing relative errors. The double float had been generally rejected—apparently without sufficient grounds—and it was therefore decided to give this method a fair trial.

The lower float was made by bending in the middle two strips of sheet tin, 8 inches long by 2 inches wide, and then soldering the bent edges together; all the angles included between the four fans, thus made, being right angles. This sub-float itself, 2 inches in height, was supported by two pieces of cork, each 2 inches in diameter by half an inch in height. One piece was secured permanently to the top of the tin, thus increasing by its own area the area of the lower float. The other, forming the surface float, was attached by a very fine iron wire. It was submerged only about an eighth of an inch, and, therefore, exercised no appreciable effect upon the

rate of movement of the lower float By varying the length of the wire, the velocity at any depth could be measured, especial care being taken to place the centre of figure of the lower float at the exact depth required, a very important matter, especially for observations at considerable distances from the point of maximum velocity

" The vertical plane in which to measure the sub surface velocities was carefully selected so as to be as nearly as possible that of the thread of the current, because the flatness of the horizontal curve in this vicinity would give, to slight deviations of the floats from the exact vertical plane, their minimum effect in inducing errors

' The velocity was determined by noting the times of transit of the floats between two cords 51 feet apart, stretched across the feeder just above the water surface A chronometer was used with all the care employed in nice astronomical observations The floats were placed in the water sufficiently far above the upper line for the lower float to sink and attain the uniform velocity of the water at the desired depth before reaching the cord Twelve series of observations were made in succession The following table exhibits the data in full with a comparison of the grand mean curve with the parabola whose equation is—

$$V = 2.5216 - 1.1\left(\frac{d - 1.65}{7.1}\right)^2$$

Sub-surface velocity observations upon a feeder of the Chesapeake and Ohio Canal —Velocities, in feet per second, of floats at various depths

Series	V_0	V_1	V_2	V_3	$V_{\frac{1}{2}D}$	V_4	V_5	$V_{6.1}$	$V_{7.1} = V_D$	Vm by equation (5)
First,	2.2787	2.4866	2.5590	2.4998		2.6154	2.3182	1.9285		
Second,	2.3302	2.5 80	2.4968	2.4998		2.4878	2.2667	1.9299		
Third,	2.4406	2.5580	2.6214	2.5620		1.8599	2.3182	1.9814		
Fourth,	2.2787	2.5590	2.3811	2.4406		2.3192	2.3182	2.0040		
Fifth,	2.2294	2.5590	2.4376	2.4406		2.4256	2.3182	1.9655		
Sixth,	2.3841	2.4366	2.6244	2.5620		2.4878	1.8889	1.9315		
Seventh,	2.3841	2.3801	2.4968	2.4998		2.2174	2.1270	1.8585		
Eighth,	2.3841	2.5680	2.4968	2.4406		2.4979	2.3721	2.0440		
Ninth,	2.3841	2.5580	2.5590	2.3841		2.4978	2.3182	1.9264		
Tenth,	2.2787	2.4958	2.5590	2.4998		2.4256	2.1702	1.7528		
Eleventh,	2.3841	2.5580	2.6932	2.4998		2.4286	2.4878	2.0856		
Twelfth,	2.2787	2.5580	2.2757	2.5620		2.4878	2.3182	2.2707		
Mean,	2.3363	2.5178	2.5170	2.4909		2.3971	2.2683	1.9632		
Parabola,	2.4626	2.5124	2.5190	2.4818	2.4428	2.4010	2.2767	2.0895	1.8725	2.3509
Difference,	−0.1263	+0.0054	−0.0020	+0.0091		−0.0039	−0.0084	−0.1263		

" The small amount of these differences proves that the curve is a para-

bola, whose axis is parallel to the water surface and 0 232 of the depth below it, a result satisfactory both as confirmatory of the Mississippi work and indicating that even a few observations, carefully taken in a favorable locality with double floats, may reveal the form of the curve exhibiting the change of velocity below the surface The mean velocity was carefully deduced from a set of observations taken across the feeder at a uniform depth, by multiplying the mean of this horizontal curve by the ratio between the velocity at its depth and the mean of the whole vertical curve It was found to be 2 0830 feet per second From this the following value of b results—

$$b = \frac{(1\ 1)^2}{2\ 0830} = 0\ 58$$

"This new value of b confirmed the inference drawn from Boileau's observations, that the quantity varied inversely with the depth and justified an attempt to deduce its equation The observations upon the Mississippi show that b must remain partly equal to 0 186 for depths varying between 110 and 55 feet, and, if the somewhat less exact measurements made upon Bayous Plaquemine and La Fourche are to be relied upon in so delicate a matter, for depths even as small as 27 feet When, however, the depth becomes 7 1 feet, a sensible increase is noticed, the quantity becoming 0 58, and when a further reduction to 0 9 of a foot is made, the quantity slightly exceeds unity, its value being about 1 1 (mean of Boileau's two results) The following expression fulfils these conditions with all needful accuracy, as is shown by the table of values —

$$b = \frac{1\ 69}{(D + 1\ 5)^{\frac{1}{2}}} \quad \ldots\ldots \quad (3)$$

Values of D in feet,	110	82	55	27	7 1	1 1	0 7
Values of b by equation (3),	0 161	0 186	0 225	0 317	0 58	1 04	1 14

"Since the rivers discussed in this report are usually deep, b will be generally taken at 0 1856. If small streams are to be considered, the above value should be substituted in equation (2) making it,

$$V = V_{d_1} - \left(\frac{1\ 69\ v}{(D + 1\ 5)^{\frac{1}{2}}}\right)^{\frac{1}{2}} \left(\frac{d - d_1}{D}\right)^2 \quad \ldots (4)$$

This is in truth a general equation, whether applied to the Mississippi river, pouring its flood of waters with boils and whirls through a channel 200,000 square feet in cross-section and more than 100 feet in depth, or to the Bayou La Fourche, flowing as smoothly as a canal through a narrow channel less than one-fortieth of the size, or even to the experimental canal, the result accords closely with the observations."

It will be remarked that the formula contains more than one unknown quantity, and that in its present shape it is only useful as a test of the accuracy of the parabolic theory as compared with observations which furnish a knowledge of the mean velocity of the stream on which they may be taken, and the depth of the axis of the curve below the surface.

Arrived so far, the authors proceed to investigate the laws which determine the position of the maximum velocity in any vertical curve, parallel to the direction of the current, and to analyse the effect of the wind upon the axis of the curve. This examination is conducted with their usual clearness and ingenuity, but, as the result they arrived at, though having an important bearing with regard to the Mississippi observations, is not applicable in its integrity to other rivers, I think it unnecessary to follow the steps by which the equation showing the effect of the wind was obtained. I would merely remark that the authors ascertained that the effect of the wind whether blowing up or down-stream, is directly proportional to its force, in the former case lowering, and in the latter raising, the axis. Also that the amount of such lowering or raising is independent of the mean velocity of the river. The point of maximum velocity on the grand mean vertical curve, after correction for the effect of the wind, was 0.317 of the depth, and the depth of the axis when subjected to a wind force is given by the formula

$$d_1 = (0.317 \pm 0.06 f)\, r,$$

in which r is the mean radius or hydraulic mean depth, and f is the number indicating the force of the wind, a calm, or a wind blowing across the stream at right angles to the current, being denoted by 0, and a hurricane by 10. Its essential sign is *positive* when the wind blows up-stream, that is it lowers the axis, and *negative* when down-stream. The greatest wind force under which observations could be conducted is denoted by 4.

The depth of the axis below the surface of the stream under the different wind forces would thus be the following, the whole depth being denoted by unity —

		$\frac{d_1}{r}$
Wind down force,	4,	0·077
" "	3,	0·137
" "	2,	0·197
" "	1,	0·257
" "	0,	0·317
Wind up force,	1,	0·377
" "	2,	0·437
" "	3,	0·497
" "	4,	0·557

The following extract from Chapter V of the report, conveying the authors' explanation of the causes which produce a variation in the form of the velocity curve will be read with interest —

"The observations already detailed prove that even, in a perfectly calm day, there is a strong resistance to the motion of the water at the surface as well as at the bottom, and that it is not wholly or even mainly caused by friction against the air One important cause of this resistance is believed to be the loss of living force, arising from upward currents or transmitted motion occasioned by irregularities at the bottom. Other causes may and probably do exist, but their investigation has, fortunately, more of scientific interest than of practical value For all general purposes it may be assumed that there is a resistance at the surface, of the same order or nature, as that which exists at the bottom As the distance of the loci of these two resistances is increased, their effect propagated by the cohesion of different particles of water to each other, is diminished Where these diminished resistances become equal, the current acquires its maximum velocity Let this point in any vertical plane parallel to the current be considered as the vertex of a parabola whose axis is parallel to the water surface, and the velocity at any depth on this plane will be given by the abscissæ of the curve, the axis of the curve being considered the axis of X, and the origin of the co-ordinates being taken at a distance from the vertex equal to the maximum velocity The parameter of this curve, or in other words its curvature, varies with a known function of the depth and mean velocity of the river The depth of the axis varies in direct proportion to the force of the wind, increasing for up-stream, and diminishing for down-stream, breezes, but without producing any effect on the curve The mean

and maximum velocities are so related to each other that when either, with the depth of the axis, is known, the other and the curve itself may be determined. It may be added, that the difference between the greatest and least velocities is always a very small fraction of the mean of the curve. The above experimental theory suggests reasons why the problem has heretofore defied all efforts for its solution, and why its study has given rise to such incongruous results. Besides the great difficulty of taking the observations with sufficient nicety to detect the very slight difference of velocity at different depths, there is a second cause of failure, namely, an almost constant change of velocity at different depths. The axis can rarely be at rest, every varying breeze, however gentle, must affect its delicate adjustment, while the stronger pulsations of a high wind must produce an oscillatory movement even greater than that on the tops of the tallest trees. Different floats, therefore, although they may pass at *the same depths below the surface*, may yet pass at very *different distances from the axis*, and thus measure the velocity at very different points of the curve. This idea may explain in part a phenomenon noticed by the observers, and recorded in the note-books of the survey as a pulse in the river, owing to which there seemed to be a regular increase and then decrease in the velocity of different floats observed consecutively at the same depth. But there are other sources of variation in the velocity. The eddies to be found in every reach of the river change their magnitude and position at each instant, and must produce corresponding oscillations in the velocity of the river at any given point. Wind magnifies the pulsations of the eddies, and thus produces a double effect upon the variation in the velocity of the given point. As an instance of the force thus exerted by the wind, it may be mentioned that a south-east storm created an eddy just above Red River Landing, more than half a mile in length, with a width nearly half that of the river, and with an up-stream current exceeding 7 miles per hour. It is manifest from these considerations, that no certainty of deducing the law experimentally can be had without taking a vast number of exceedingly accurate observations, and even then it seems remarkable that great discrepancies should not remain uneliminated."

Returning to the general equation of the velocity curve in a vertical plane, namely $V = V_{d1} - \left(\frac{1\cdot690}{(D + 1\cdot5)^{\frac{1}{2}}}\right)^{\frac{1}{2}} \left(\frac{d - d_1}{D}\right)^2$ in which as already explained

V, is the velocity at any point in the curve

V_{d_1}, the maximum velocity, or that at the axis of the curve

d, the depth below the surface of the point whose velocity is V

d_1, the depth of the axis below the surface

D, the whole depth

v, the mean velocity of the river

Let
$$\left(\frac{1.69}{(D + 1.5)^{\frac{1}{2}}}\right)^{\frac{1}{2}} = b^{\frac{1}{2}}$$

Then the general formula becomes

$$V = V_{d_1} - (bv)^{\frac{1}{2}} \left(\frac{d - d_1}{D}\right)^2$$

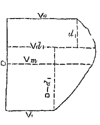
In the Mississippi, and the other streams measured in the report with a depth ranging from 27 to 110 feet, it has been shown that $b^{\frac{1}{2}} = (.1856)$

Let V_m be the mean velocity on any curve in the vertical plane

V_0 the velocity at the surface

V_D the velocity at the bottom, as shown in the annexed diagram

Then V_m D represents the area of the figure, and by the properties of the parabola



$$V_m D = \tfrac{2}{3} (V_{d_1} - V_0)\, d_1 + V_0 d_1 + \tfrac{2}{3} (V_d - V_D)(D - d_1) + V_D (D - d_1)$$

$$V_m = \tfrac{2}{3} V_{d_1} + \tfrac{1}{3} V_D + \frac{d_1}{D} (\tfrac{1}{3} V_0 - \tfrac{1}{3} V_D)$$

In the general formula, making successively $d = 0$ and $d = D$

we have $V_0 = V_{d_1} - (b\,v)^{\frac{1}{2}} \left(\frac{d_1}{D}\right)^2$

and $V_D = V_{d_1} - (b\,v)^{\frac{1}{2}} \left(\frac{d_1 - D}{D}\right)^2$

By substituting these values of V_0 and V_D in the above expression for V_m,

$$\text{we have } V_m = V_{d_1} - (b\,v)^{\frac{1}{2}} \left(\frac{D^2 + 3d_1 (d_1 - D)}{3 D^2}\right)$$

$$\text{and } V_{d_1} = V_m + (b\,v)^{\frac{1}{2}} \left(\frac{D^2 + 3d_1 (d_1 - D)}{3 D^2}\right)$$

By substituting this expression in the equation for V, and reducing, we find

$$V = V_m + (b\,v)^{\frac{1}{2}} \left(\frac{D^2 - 3d_1 D - 3d^2 + 6dd_1}{3 D^2}\right)$$

$$\text{Let } d = \frac{D}{2}$$

$$\text{then } V_{\frac{D}{2}} = V_m + \frac{(b\,v)^{\frac{1}{2}}}{12}$$

"This equation reveals a fact of great practical importance in gauging

rivers, namely that the ratio of the mid-depth to the mean velocity in any vertical plane is independent of the width and depth of the stream—except for their almost unappreciable effect on b—absolutely independent of the depth of the axis, and, from the small numerical value of $\frac{1}{12}b^{\frac{1}{2}}$, nearly independent of the mean velocity "

It remains to be seen how the equation $V_{\frac{D}{2}} = V_m + \frac{1}{12}(b\,v)^{\frac{1}{2}}$ is to be turned to practical account

If a series of mid-depth velocities be obtained by observation at intervals across the stream, and if they are substituted successively for $V_{\frac{D}{2}}$ in the formula, $V_m = V_{\frac{D}{2}} - \frac{1}{12}(bv)^{\frac{1}{2}}$, the resulting values will be expressions for the mean velocities of the different divisions in terms of $v^{\frac{1}{2}}$ and known quantities "The sum of the products of these expressions by the corresponding division areas should then be placed equal to the product of v by the total area of cross section The resulting equation involving only v and $v^{\frac{1}{2}}$ and known terms, may be readily solved, and the values of v determined. There will be two values, both positive, one the lesser, corresponding to the actual case in nature, when the velocity at the axis is the greatest of any, the other the greater, corresponding to the hypothetical condition that this velocity shall be the least It need hardly be added that the former is the true mean velocity of the river It is believed that the latter process of computation, applied to careful observations will furnish the most accurate determination of the discharge of a large stream which can possibly be obtained "

The above is the most important formula for determining the mean velocity and discharge of a stream that has resulted from the labors of Messrs Humphry and Abbot Its value evidently depends on the reality or otherwise of the parabolic theory of the sub-surface velocities in a vertical plane parallel to the current This theory has been subjected by the authors to a very severe test, by application to groups of all the observations which were made by them and their surveying parties on the Mississippi and several Bayous and on the feeder of the Chesapeake and Ohio canal, as also to the small experimental canals of Captain Boileau The results exhibit a surprising correspondence between their theory and the observations The question now is, whether the combination of a great number of observations, which result in exhibiting the sub-surface velocities

in a well defined parabolic curve is sufficient to prove the existence of a law, and whether, supposing a law established, it can be applied with confidence to the measurement of the velocity and discharge of streams generally, by means of a moderate number of observations of the mid-depth velocity taken at intervals across the stream?

It is to be observed that although the combination of a number of observations on the Mississippi, results in giving a parabolic curve to the velocities in the vertical planes parallel to the current, there are great discrepancies from that curve in any single set of the observations in any one vertical plane, as the reader may ascertain for himself by plotting the observations given in the Tables appended to these remarks So great indeed are the discrepancies, that it would be impossible for any one to say, not only that the figures formed by connecting the termini of the lines which represent the velocities, bear any resemblance to a parabola, but that they resemble any curve whatever An Engineer who might wish to apply the formula given by Messrs Humphry and Abbot for the determination of the mean velocity of any river of which he had to ascertain the discharge, would naturally conclude that the same discrepancies which are displayed in any single series of observations on the Mississippi would be liable to occur in his observations, and unless those observations were repeated very frequently, and at various sites, he could never feel confident of having entirely eliminated the differences, in fact, he could not feel sure that the formula would be applicable to his observations unless he repeated for himself the various steps by which it was arrived at on the Mississippi The experiments on that river were conducted on a gigantic scale, and the precision with which the authors of the report have elicited from a confused heap of observations, a coherent and systematic treatise on the motion of rivers, is worthy of the greatest admiration The whole report is a perfect model, and on the subject of which it treats, there is certainly nothing to be compared to it in the language Even if their theory does not admit of general application, the record of the observations, which the authors have spared no pains to exhibit faithfully and fully, possesses great interest in itself, and will furnish those who study it with much valuable information, which is not to be obtained in any other work The authors do not encourage a comparison between the surface and mean velocities in any vertical plane, but should the reader wish to judge of the approximate ratio which the two bear to each other, he has the means of doing so, and of arriving at

a higher degree of accuracy than he could attain by consulting former works on hydraulics. The mid-depth and the mean velocities may also be compared with advantage. I thought at first of adding two columns, showing these ratios in the Tables of observations appended, but on consideration, it appeared to me preferable to omit them, as in consequence of the observations not having been invariably conducted at equal intervals from surface to bottom of the stream, and of their not having in many cases been continued to the immediate proximity of the bottom, correct means are not attainable, and some interpolations would have had to be introduced which would have either extended the tables to an inconvenient length, or have served to confuse them. The reader is therefore recommended to make the comparison between the surface, mid-depth, and mean velocities in the vertical planes, for himself, and also to plot on section paper diagrams of the velocities for each set of observations. He will thus be able to judge of the difference between the actual velocities and those which would be obtained from the formula, much better than by a simple comparison of their numerical values, without diagrams.

One cannot help regretting, when Messrs. Humphry and Abbot have given so much valuable information, and have carried on experiments on such an extended scale, that besides observations of the sub-surface velocities at various distances from the edge of the channel, at a number of different stations, they had not also arranged a series of such velocities at equal distances the whole way across the stream at one station at least, so that, for example, if a plot of the cross-section of the stream had been divided into a number of squares or rectangles, a like number of velocity observations might have been exhibited. Had this method been adopted, the effect of the resistance of the bed of the stream on the velocities could probably have been traced more clearly than would be possible by the method they pursued. Some observations have recently been conducted on this principle in France by M. Bazin, who has also executed a number of experiments on the velocity and discharge of channels under different conditions, which lead to conclusions greatly at variance from those generally received. I hope to have an opportunity before long of furnishing some notes on his experiments, which I may add were published several years later than the Mississippi report.

A few words more may be added to explain, that Messrs. Humphry and Abbot after arriving at a number of formulæ to guide them in the prose-

cution of their researches on the Mississippi, with a view to acquire a certain knowledge of the measures which were best calculated to check injurious flooding of the low alluvial lands, and to dispose of the additional water which would have to be carried off in the channel of the river, entered into a disquisition on the theory of running water, from a different point of view from that described in the preceding pages. They took up the formula commonly used, which is known as Prony's or Eytelwein's, and which expresses the mean velocity of a stream in terms of the fall of the surface and the hydraulic mean depth, united to a co-efficient determined by observation. They arrived at a new formula, which differs materially from the received one, and they have supported it by reference to various experimental data. The investigation, though interesting, is on the whole of a more theoretical character than that above described, and the data are scanty compared with those on which the latter is founded. For the present I confine myself to a mere statement of the formula, leaving it to the reader to test it, as opportunity may offer.

For a channel with a rectangular cross section—

$$V = \left[\sqrt{0.0064b + (195 r_1 s^{\frac{1}{2}})^{\frac{1}{2}}} - 0.08 b^{\frac{1}{2}}\right]^2$$

For a river channel—

$$V = \left[\sqrt{0.0081b + (225 r_1 s^{\frac{1}{2}})^{\frac{1}{2}}} - 0.09 b^{\frac{1}{2}}\right]^2$$

Or, for rivers whose mean radius exceeds 12 or 15 feet—

$$V = \left[(225 r_1 s^{\frac{1}{2}})^{\frac{1}{4}} - 0.0388\right]^2$$

where

V is the mean velocity

$b = \dfrac{1.69}{(r + 1.5)^{\frac{1}{2}}}$, r being the mean radius or hydraulic mean depth.

r_1 = area of section divided by its whole perimeter

s = fall in unity

J. C. A.

TABLE I

Sub-surface velocities at high stages of the river, the water being about 110 feet deep

Station at Carrolton	Gauge	Mean velocity of river	Wind	Distance from base	Depth	No of observs at each point	Velocity in feet per second at various depths below water surface								
							Surface	3 feet	6 feet	18 feet	36 feet	54 feet	72 feet	90 feet	102 feet
I.	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII	XIII	XIV	XV	XVI
	13 7	5 8151	down 2	350	110	1	6 6666	6 6666	6 6666	6 6666	6 6666	6 4516	6 2500	5 8823	5 2631
	9 4	3 8157	up 2	430	110	2	3 9215	4 2553	4 1666	4 2553	4 3478	4 3478	4 2553	4 0816	3 8461
	9 4	3 8157	up 2	920	110	2	3 6363	3 7037	3 7735	3 8461	3 8461	3 8461	3 7735	3 7037	3 4482
	9 4	3 7703	0	1000	110	10	3 6633	3 7456	3 7526	3 8913	3 8537	3 7456	3 6103	3 6633	3 7246
	9 5	3 8919	0	350	110	6	4 0735	4 1666	4 1496	4 0816	4 0653	4 2553	4 1241	3 7526	3 4482
	10 6	4 1580	up 2	430	105	2	4 4400	4 3500	4 7600	4 7600	4 7600	4 6500	4 5500	4 6500	4 4400
Prime base,	10 6	4 1580	up 2	540	105	2	4 5500	4 5500	4 7600	4 7600	4 6500	4 5500	4 3500	4 1700	4 0000
	10 7	3 6420	up 3	960	105	2	3 7000	3 9200	4 0000	3 7700	3 8500	3 7700	3 7000	3 5700	3 5100
	10 7	4 0932	up 3	300	110	9	4 5666	4 5666	4 2511	4 5877	4 8548	4 7176	4 5151	4 4444	4 1666
	10 8	4 2523	up 1	300	110	16	4 2738	3 9529	4 1755	4 1241	4 1241	4 0082	3 8025	3 6298	3 5087
	11·0	4 3079	down 1	900	110	16	4 3961	4 3671	4 3961	4 4848	4 5151	4 4747	4 4347	4 3864	4 4646
	11 6	4 2343	up 2	200	110	2	4 1666	4 0916	4·0000	4 2553	4 2553	4 2553	4 1666	4 0816	4 0000
	11 6	4 2343	up 2	800	110	2	4 5454	4 5454	4 5454	4 5454	4 5454	4 6511	5 1282	5 0000	4 6511
True mean,		4 1216	up 0 8				4 2301			4 2984	4 3463	4 2745	4 1580	4 0528	3 9481

N B —The figures underlined in this and the following tables represent velocities obtained by interpolation

TABLE II.

SUB-SURFACE velocity observations at high stages of the river, the water being about 70 feet deep

I	II.	III	IV	V	VI	VII.	Velocity in feet per second at various depths below water surface.						
Station at Carrolton	Gauge.	Mean velocity of the river	Wind	Distance from base	Depth	No of observations at each point	VIII Surface	IX ½ fathom	X 1 fathom	XI [illegible] fathoms.	XII 6 fathoms	XIII 9 fathoms	XIV 11 Fathoms
	feet	feet		feet	feet								
Prime base,	9 4	3 8157	up 2	1400	65	2	3 1250	3 0769	3 1746	3 2786	3 4482	3 3333	3 2239
„	9 7	3 8913	0	1600	65	8	2 8902	2 9155	3 0961	3 0536	3 1300	3 1448	3 1548
Race-course base,	10 6	4 1580	up 2	1360	70	2	4 4400	4 5500	4 6500	4 4400	4 0800	4 0000	3 8500
Lock's base,	10 7	3 6420	up 3	1700	70	2	3 8600	4 6311	4 3500	4 2600	4 3500	4 3500	4 1700
„	10 7	3 6420	up 3	2070	70	2	4 3500	4 5500	4 6500	4 5500	4 5500	4 1700	3 8500
Prime base,	10 8	4 1271	down 1	1720	65	8	3 2628	3 4724	3 6430	3 7107	3 7037	3 5589	3 4724
„	11 1	4 3773	down 1	1620	65	16	3 5338	3 4845	3 6700	3 6363	3 7316	3 5651	3 4845
„	11 6	4 3051	0	1500	65	2	3 8461	3 8461	3 9215	4 0816	4 0816	4 0816	3 8461
True mean,	.	4 1279	down 0 1			.		3 5503		3 6551	3 6999	3 5843	3 4917

TABLE III

SUB-SURFACE velocity observations at high stages of the river, the water being about 55 feet deep

I	II.	III	IV	V	VI.	VII	Velocity in feet per second at various depths below water surface					
Station at Carrolton.	Gauge	Mean velocity of the river	Wind	Distance from base	Depth	No of observations at each point	VIII Surface	IX ½ fathom	X 1 fathom	XI 3 fathoms	XII 5 fathoms	XIII 6 fathoms.
	feet	feet		feet	feet							
Race-course base,	10 6	4 1580	up 2	1970	50	2	3 9215	3 6333	3 8461	3 8461	3 7062	3 6363
Prime base,	10 8	4 1271	down 1	1900	55	8	2 9631	2 8290	2 8944	3 0629	3 1696	2 9895
" " ..	11 2	4 4240	0	1850	55	16	2 6774	2 1811	2 6213	2 5642	2 6110	2 6042
" "	11 6	4 3051	0	1900	55	2	3 1250	3 1250	3 1746	3 1746	3 2786	2 9850
True mean .		4 3117	down 0·1				2 7623		2 8263	2 8311	2 8965	2 8152

TABLE IV

SUB-SURFACE velocity observations at low stages of the river, the water being about 100 feet deep

I.	II	III.	IV	V	i	VII	Velocity in feet per second at various depths below water surface														
Station at Carrolton.	Gauge	Mean velocity of the river	Wind.	Distance from base	Depth	No of observations at each point	VIII Sur face	IX. 1 fath	X 2 fath	XI 3 fath	XII 4 fath	XIII 5 fath	XIV 6 fath	XV 7 fath	XVI 8 fath	XVII 9 fath	XVIII 10 fath	XIX 11 fath	XX 21 fath	XXI 13 fath	XXII 14 fath
	feet.	feet.		feet.	feet.																
'rime base,	1 8	1 9458	dwn 2	425	100	4	2 2222	2 2297	2 1575	2 1459	2 0264	2 0513	2 0471	2 0081	1 9286	1 9581	1 9139	1 9120	1 8416	1 8656	1 8467
"	1 8	1 9045	" 2	900	100	4	2 2222	2 2962	2 3753	2 3809	2 3809	2 3202	2 2753	2·2002	2 2447	2 2372	2 2422	2 1716	2 1276	2 1074	2 1299
"	1 1	1 6577	" 3	400	100	4	1 3422	1 3746	1 3404	1 3513	1 3495	1 3140	1 3227	1 3315	1 3029	1 3157	1 3012	1 2886	1 2970	1 2484	1 2000
"	1 0	1 6552	" 3	850	100	4	2 1276	2 1231	2 1231	2 1119	2 1119	2 0618	2 0471	2 0408	2 0305	2 0000	2 0020	2 0610	2·0000	1 9417	1 8518
"	0 9	1 5973	" 3	300	95	8	1 8518	1 7437	1 8333	1 9230	1 8840	1 8450	1 8667	1 8885	1 8484	1 8083	1 7444	1 6806	1 5832	1 4858	1 3614
rue mean,	.	1 7259	" 2 7				1 9362	1 9185	1 9438	1 9727	1 9394	1 9062	1 9043	1 8929	1 8672	1 8596	1 8247	1 7996	1 7388	1 6891	1 6390

TABLE V

SUB-SURFACE velocity observations at low stages of the river, the water being about 80 feet deep

Station	Gauge	Mean velocity of the river	Wind	Distance from base	Depth	No of observation at each point	Velocity in feet per second at various depths below water surface												
							Surface	1 fath	2 fath	3 fath	4 fath.	5 fath	6 fath	7 fath	8 fath	9 fath	10 fath	11 fath	12 fath.
	feet	feet.		feet.	feet.														
Carolton prime base,	1 0	1 6610	dwn 2	1250	80	4	1 9357	1 9596	1·9342	1 9089	1 8707	1 8628	1 8961	1 8961	1 8311	1 8281	1 7726	1 7178	1 5850
Baton Rouge, lower base,	1·9	2 1603	0	1100	75	8	2 7200	2 7500	2 7200	2 6991	2 6585	2 6179	2 5605	2 5032	2 4846	2 4661	2 4221	2 3781	2 1930
"	4 8	2 2377	0	1550	80	8	2 3000	2 3300	2 3000	2 2803	2 2792	2 2779	2 2295	2 1811	2 1716	2 1622	2 1174	2 0726	2 0597
True mean, .	.	2 0914	dn 0·4				2 3951	2 4239	2 3998	2·3738	2 3492	2 3134	2 2952	2 2530	2 2287	2 2170	2 1703	2 1240	2·0181

TABLE VI

SUB-SURFACE velocity observations at low stages of the river, the water being about 60 feet deep

Station	Gauge	Mean velocity of the river	Wind	Distance from base	Depth	No of observs at each point	Velocity in feet per second at various depths below water surface									
							Surface	1 fath	2 fath	fath	4 fath	5 fath	6 fath.	7 fath	8 fath	9 fath
	feet.	feet		feet	ft											
Carrolton prime base,	1 5	1 8832	0	1500	55	4	2 1716	2 1599	2 1575	2 1119	2 1835	2 1368	2 107	2 0534	1 9665	
" "	1 5	1 8832	0	1800	55	4	1 9398	1 9065	1 8034	1 7746	1 7731	1 6694	1 6488	1 5898	1 5308	1 5662
" "	1 0	1 6610	down 2	1600	55	4	1 6806	1 6849	1 6708	1 6597	1 6434	1 5786	1 5209	1 4630	1 4051	
Baton Rouge upper base,	4 9	2 4664	0	2050	65	8	2 8955	2 8571	2 7695	2 7855	2 8012	2 8091	2 785[illegible]	2 8290	2 7816	2 6631
" "	4 9	2 1603	down 1	600	60	8	2 9368	2 9674	2 9205	2 8737	2 7792	2 6847	2 666[illegible]	2 6491	2 5561	2 4631
" "	4 8	2 4664	0	1900	55	8	2 2051	2 2962	2 3458	2 3953	2 [illegible]880	2 3474	2 2463	2 1119	2 0837	2 0755
True mean,		2 1285	down 0 4				2 3804	2 3910	2 3887	2 3504	2 3404	2 2929	2 2434	2 1988	2 1379	2 0628

TABLE VII

Sub-surface velocity observations upon the Bayous

Locality	Distance below upper mouth	Stage below N W of 1851	Approximate mean velocity of Bayou	Wind	Distance from base	Depth	No of floats	Velocity in feet per second at						
								Surface	5 feet deep	10 feet deep	15 feet deep	20 feet deep	Point of max vel	Bottom
	feet	feet	feet		feet	feet								
Bayou Plaquemine,	800	0·6	5·41	down 2	150	27	8	6·50	6·52	6·35	6·30	6·02		
					By formula,			6·485	6·48	6·406	6·267	6·054	6·491*	5·644
					Difference,			+ 0·015	+ 0·040	− 0·056	+ 0·033	− 0·634		
Bayou La Fourche,	2,500	1·3	2·73	up 0·7	100	27	6	3·16	3·23	3·25	3·22	3·15	*	
					By formula,			3·163	3·231	3·249	3·221	3·141	3·250†	2·950
					Difference,			− 0·003	− 0·001	+ 0·001	− 0·001	+ 0·009		

* Depth 2·2 feet

† Depth 9·5 feet.

TABLE VIII

SUB-SURFACE velocity observations upon the Mississippi, at medium stages, the depth being about 65 feet

Locality	Gauge	Approximate mean velocity of river	Wind	Distance from base	Depth	No of observa at each point	Velocity in feet per second at various depths below water surface.							
							Surface	10 feet	20 feet	30 feet	40 feet	50 feet	60 feet	Bottom
	feet	feet		feet	feet									
Columbus, Kentucky,	17·7	4·6679	down 1	900	70	3	7·6923	6·2500	6·0606	6·0606	6·2500	6·2500		
	26·0	4·7183	,, 3	700	75	1	6·4516	7·1429	7·1429	8·0000	7·1429	6·8965		
	22·8	4·2758	,, 1	900	75	3	6·4516	6·4516	6·6666	6·0606	6·4516	6·2500		
	20·4	3·9733	up 3	900	70	3	5·0000	5·1282	5·4054	5·4054	5·5555	6·0606		
	23·7	4·7011	,, 2	500	75	3	4·2553	4·6511	4·7619	4·8780	4·8780	5·0000		
	26·2	5·0164	,, 1	500	75	3	5·0000	5·0000	5·4054	5·1282	5·0000	5·1282		
	21·2	4·0716	,, 2	700	70	3	4·6511	4·8780	5·1282	5·1282	5·1282	4·8780		
	20·9	4·1013	,, 0	700	70	3	4·7619	5·2631	5·0000	5·1282	5·1282	5·1282		
	18·3	3·4344	down 2	500	70	3	3·7735	3·6363	3·6363	3·7037	3·7037	3·7037		
	14·7	3·0722	,, 1	700	65	3	3·7037	3·9215	3·7735	3·8461	3·9215	3·9215		
	11·9	2·5908	up 3	700	60	3	2·8571	2·7027	3·1250	3·1746	3·1250	3·0769		
	9·5	2·4391	,, 4	900	60	3	2·6666	2·9850	2·8985	2·9411	2·9850	2·9411		
	11·5	2·5141	down 2	700	60	3	3·2258	2·9850	3·2258	3·3898	3·2258	3·2786		
	6·5	2·1269	up 4	700	55	3	2·0618	2·1978	2·2472	2·4096	2·3529	2·4096		
	4·0	1·7464	,, 3	900	55	3	1·9417	2·0833	2·0833	2·0833	2·1978	2·1276		
	3·2	1·5214	,, 2	900	55	3	1·7094	2·0618	2·0618	2·0408	2·0618	1·9801		
	11·8	3·5003	,, 1	700	60	3	3·1746	4·0000	4·0000	4·1666	4·3478	4·1666		
	15·0	3·7290	,, 3	800	65	3	4·2553	4·2553	4·3478	4·4444	4·1666	4·6511		
True mean,		3·4070	up 1·2				3·9826	4·0864	4·1659	4·1917	4·1843	4·1875		
By formula,							3·9875	4·0959	4·1667	*4·1395	4·1953	4·1531	4·0733	4·0193
Difference,							−0·0049	−0·0095	−0·0005	−0·0081	−0·0110	+0·0344		

* Maximum velocity 4·2025 (depth 33·8 feet).

TABLE IX

SUB-SURFACE velocity observations upon the Mississippi at its highest stage, the depth being about 75 feet

Locality	Gauge.	Approximate mean velocity of river	Wind	Distance from base	Depth	No of observations at each point	Velocity in feet per second at various depths below water surface					
							Surface.	40 feet	50 feet.	60 feet	70 feet	Bottom.
	feet	feet.		feet	feet							
Vicksburg,	47 4	6 9386	up 2	1600	75	1	7 69	8 33	8 00	9 09	8 70	
"	44 6	6 4445	0	1700	75	2	7 41	7 14	6 90	6 45	5 88	
True mean,		6 6092	up 0 7		.	.	7 50	7 54	7 27	7 33	6 82	
By formula,		.	..		.		7 5339*	7 4551	7 3370	7 1795	6 9545	6 8694
Difference, .						.	−0·0339	+0 0849	−0 0670	+0 1505	−0 1345	

* Point of maximum velocity 7 5782 (depth 15 feet)

TABLE X

Sub-surface velocity observations upon the Mississippi at a medium stage, the depth being about 55 feet

Locality	Gauge	Approximate mean velocity of river	Wind	Distance from base	Depth	No of observs at each point	Velocity in feet per second at various depths below water surface						
							Surface	10 feet	20 feet.	30 feet	40 feet	50 feet	Bottom
	feet	feet		feet	feet								
Vicksburg,	17 8	4 0394	down 1	1900	55	2	4 88	4 88	5 00	4·76	4 44	5 00	
	17 7	3 9181	„ 1	1800	55	3	4 76	4 82	4 88	4 88	4 55	4 35	
	17 7	3 9181	„ 1	2200	65	2	4 67	4 76	4·76	4 00	3 17	2 34	
	17 7	3 9181	„ 1	1300	45	1	4 76	4 26	3 35	3 23	3 11	2 99	
	17 3	3 8652	0	2200	65	2	4 17	3 97	3 77	3 51	3 92	4 00	
	17 3	3 8652	0	2000	60	2	5 00	4 83	4 65	4 55	4 08	3 51	
	17 3	3 8652	0	1900	65	2	4 55	4 28	4 00	4 44	4 26	4 00	
	24 5	4 7366	down 2	1900	65	2	4 94	5 41	5 88	5 56	5 88	6 25	
	24 5	4 7366	„ 2	600	45	2	3 13	3 45	3 77	3 64	3 28	2·92	
	24 5	4 7366	„ 2	1100	45	2	4 86	4 76	4 55	4 55	4 44	4 15	
True mean,	.	4 1599	down 1	.			4 5810	4 5700	4 5375	4 3945	4 1850	4 0190	
By formula,							* 4 5676	4 5705	4 5153	4 4020	4 2307	4 0012	3 8657
Difference,							+ 0·0134	− 0 0005	0 0222	− 0 0075	− 0 0457	+ 0 0178	

* Point of maximum velocity 4 5764 (depth, 5 5 feet)

No CLXXXVIII

ON COLORING WALLS

Note on the process of Coloring and Ornamenting the Walls of Rooms in Indian Houses Prepared in the Garrison Engineer's Office, Calcutta

[As much difficulty is often experienced in up-country stations in getting the interior walls of rooms properly colored by common mistrees, I have been able, through the courtesy of the Garrison Engineer, Calcutta, to give some recipes for a few of the most agreeable colors, and have added two or three patterns, which may be useful These patterns are half the proper size, but can easily be enlarged to scale, and stencil plates of wood, tin or sheet iron prepared from the enlarged drawings Two more designs will be given with the next number —ED]

When the walls are rough, and not lime plastered, they are to be enamelled with lime plaster, so as to make the surface smooth Then thick curd or *chánd* (छाना), چهنا mixed with lime water, or simply milk and water of equal proportions, is to be washed over the surface, to form a body for the water coloring

The water color to be mixed with half milk and half water, with white of eggs, and pure China glue, the latter previously boiled in water and made into liquid The color so prepared, to be laid carefully on the walls, in one coat, with an English brush, so that no cut shades be visible on the walls

Labor for coloring, about 2 annas 6 pie per 100 superficial feet

Ditto for flowers in the corners, &c, according to size and description, from 1 anna 6 pie to 3 annas each

Ditto for border or lining with different colors, according to size and description, from Rs 1-4 to 1-12 per running foot.

Statement showing rates and ingredients for different descriptions of water coloring, borders, flowering, &c

STONE COLOR, Light

		RS	A	P
Whiting powder, 1 seer,		0	2	0
Umber, burnt, ½ chittack,		0	0	7½
Chrome yellow, 2 chittacks,		0	4	0
Glue, 2 chittacks,		0	2	0
Vermilion, China, ½ tollah,		0	1	3
Total,		0	9	10½

CANARY, Light

		RS	A	P
Whiting powder, 1 seer,		0	2	0
Glue, 2 chittacks,	...	0	2	0
Chrome yellow, 2 chittacks,		0	4	0
Total,		0	8	0

BUFF, Light

		RS	A	P
Whiting powder, 1 seer,	.	0	2	0
Glue, 2 chittacks,		0	2	0
Chrome yellow, 2 chittacks,		0	4	0
Yellow ochre, 1 chittack,		0	0	1
Total,	.	0	8	1

LABONE, Medium

		RS	A	P
Whiting powder, 1 seer,	.	0	2	0
Glue, 2 chittacks,		0	2	0
Chrome yellow, 4 chittacks,		0	8	0
Mecna, 1½ chittacks,		3	12	0
Total,	..	4	8	0

ALIF, GREEN, Light

		RS	A	P
Whiting powder, 1 seer,	.	0	2	0
Chrome yellow, ½ chittacks,	..	0	1	0
Glue, 2 chittacks,	.	0	2	0
French green powder, 2 chittacks,	.	0	5	0
Total,	..	0	10	0

GREEN, Light.

		RS	A	P
Whiting powder, 1 seer,	,	0	2	0
French green powder, 4 chittacks,		0	10	0
Glue, 2 chittacks,	...	0	2	0
Total,	.	0	14	0

BROWN, Medium

Whiting powder, 1 seer,		0	2	0
Glue, 2 chittacks,		0	2	0
Burnt umber, 3 chittacks,	.	0	3	9
Meena, 3 chittacks,		7	8	0
Total,		7	15	9

BLUE, Light

Whiting powder, 1 seer,		0	2	0
Glue, 2 chittacks,	.	0	2	0
Prussian blue, 2 chittacks,		0	3	0
Total,	.	0	7	0

PURPLE, Light

Whiting powder, 1 seer,		0	2	0
Glue, 2 chittack,		0	2	0
Meena, 2 chittacks,		5	0	0
Prussian blue, 2 chittacks,	..	0	3	0
Total,		5	7	0

PINK, Light

Whiting powder, 1 seer,	.	0	2	0
Glue, 2 chittacks,		0	2	0
Meena, 2 chittacks,		5	0	0
Vermilion, China, 2 chittacks,		1	9	0
Total,		6	13	0

FINE WHITE-WASHING, 2 COATS

Stone lime, ½ chittack,		0	0	4
Water lime, 1 seer,		0	0	6
Shell lime, ¾ seer,		0	0	9
Eggs, curd, sugar, pots, scaffolding, &c.,	..	0	1	9
Labor,	..	0	4	8
Total,		0	8	0

No CLXXXIX

ROUTE SURVEY FROM NEPAL TO LHASA.

(2nd Paper)

Narrative Report of a Route-survey made by Pundit————, from Nepal to Lhasa and thence through the upper Valley of the Brahmaputra to its source Drawn up by CAPTAIN T G MONTGOMERIE, R E, *of the G T Survey, in charge of the Trans-Himalayan Survey Parties*

THE latitude observations were taken with a large sextant of 6-inch radius, and have been reduced in the G T S Computing Office There is no doubt but that the Pundit is a most excellent and trustworthy observer In order to see this, it is only necessary to look at the list given by him At any one point, the results deduced from a variety of stars differ *inter se* so very little, that it is not too much to say that the mean must be true within a limit of a minute

The merits of the route-survey are more difficult to decide upon, but the means of testing the work are not wanting The bearings from point to point were observed with a compass, and the number of paces between were counted From the bearings and number of paces there was no difficulty in computing the latitude and departure in paces, or the number of paces that the route had advanced in latitude, and also in longitude In order to determine the value of the pace, there were, first, the latitudes derived from the astronomical observations determined during the route-survey, second, the latitudes and longitudes of Kathmandû, of the Mansarowar lake, of places in Kumaon, and, lastly, the longitudes which

Turner determined by his route-survey running nearly due north from the Chumuláií peak Turner's route forms a most important check upon the Pundit's work, and prevents any accumulation of error which might occur in a route-survey carried over such a great space as 9 degrees of longitude As far as the longitudes are concerned, that of Kathmandû, which has hitherto been accepted as approximately correct, was not found to be quite in accordance with the data forthcoming It was consequently necessary to re-determine the longitude

Colonel Crawford's trigonometrical survey and map undoubtedly still supply the most reliable data available as to the position of Kathmandû, though his observations were made as far back as the year 1802

No member of the G T Survey of India has hitherto been allowed to use a surveying instrument in Nepal, but, by means of stations in British territory, a number of peaks have been accurately determined to the north of the Nepal valley. Several of these peaks have fortunately proved to be identical with those determined by Crawford

Crawford's Mount Daibun, or	L,	corresponding with	G T S,	No	XXV
Do	do,	D	do	do, ,,	XXI
Do	do,	C	do	do, ,,	XX
Do	do,	B	do	do, ,,	XVIII

Now, in Vol XII of the "Asiatic Researches," Crawford's distance of

Mount Daibun	(or XXV G T S)	from Kathmandû	is given as		85⅘	geographical miles
Do of D	(or XXI do)	do	do		48	,, ,,
Do of C	(or XX do)	do	do		59	,, ,,
Do of B	(or XVIII do)	do	do		68	,, ,,

Taking the G T S positions, of the above points, we find that the distances given above, intersect in points varying in longitude from 85° 16½′, to 85° 19′, and varying in latitude from 27° 42′ to 27° 43′ According to Crawford's map,* the Daibun peak lies 25° E of north from Kathmandû, that bearing with the distance given above, viz, 85⅘ geographical miles, would put Kathmandû in latitude 27° 43′, longitude 85° 16½′ Crawford's latitude of Kathmandû, by astronomical observations,† is 27° 42′ From the above it has been concluded that Kathmandû is in N latitude 27° 42½′, and E longitude 85° 17′ 45″

It is greatly to be regretted that the Messrs Schlagintweit did not

* A MS map in the G T Survey Office

† See page 255, Vol. XII, "Asiatic Researches" London edition

finally determine the longitude of Kathmandû in 1857, when they received permission to use their instruments in the Nepal valley The longitude might have been determined with indisputable accuracy by the simple expedient of observing the azimuth of one or more of the G T S peaks north of Kathmandû The Messrs Schlagintweit state that they saw these peaks, and recognized them as those fixed by the G T Survey, it is, consequently, all the more difficult to imagine why this great opportunity was lost Their longitude of Kathmandû was determined by a chronometer, but as the time depends upon a single day's set of altitudes taken too near to the meridian, it cannot be accepted as conclusive, but, as far as their observations can be relied on, they tend to confirm the longitude* adopted above, viz, 85° 17′ 45″

The longitudes of the points in Kumaon have been derived from the Stracheys' map †, and are known from the adjacent G T S peaks to be correct within a very small limit The longitude of Gyangze-jong (or Jhansû-jong) has been taken from Turner's survey of the road from Bhootan to Tibet, made in 1783 Turner's longitude of the Chumulárí peak is 89° 18′, the G T S longitude being 89° 18′ 43″ This coincidence no doubt is fortuitous, as there is an error of 11′ in the longitude of the origin of his survey, however it may have happened, Turner's longitudes up to Chumulárí seem to be correct, for Captain Godwin-Austen, whilst surveying in Bhootan, ascertained that the village of Pháií, close to the Chumulárí, is very nearly in the longitude ascribed to it by Turner Turner moreover puts Tassisudon in longitude 89° 41′, and Captain Austen in 89° 40′

It may, consequently, be assumed that the longitude of Turner's route near the Chumulárí peak is nearly correct From the neighbourhood of the Chumulárí to Jhansû-jong, Turner's route runs nearly due north, and therefore any error in his estimate of distances would have a very small effect on the longitude This is fortunate, as it is not known how Turner measured his distances, though he specially states that he took bearings with a compass The distance between Chumulárí and Jhansû-jong is only about 80 miles, and as the bearing is so northerly (viz, 20° E of N), it may be concluded that any error in the distance has had but small effect on the longitude The longitude of Gyangze has therefore been assumed from Turner to be 89° 31′ Turner observed the latitude at Tashil-

* The Schlagintweit's longitude of Kathmandû in terms of the G T Survey is 85° 15′ 34″.

† Compiled in the Surveyor General's Office, Calcutta, April 1850

umbo (Shigátze), and made it 29° 4′ 20″, the Pundit makes it 29° 16′ 32″ Turner's latitude of Chumulári is 28° 5′, the G T S latitude is 27° 50′ Turner very possibly was not accustomed to take latitudes, and as the Surveyor (Lieutenant S Davis) sent with him was not allowed to go beyond Tassísudon, it is not to be wondered that there are differences in his latitudes The comparison of several latitudes now well-known, tend to show that the semi-diameter of the sun may have been omitted by Turner, as his observations were to the sun only.

The Pundit's observations at Shigátze extend over many days, and include thirteen observations to the sun and a variety of southern stars, as well as to the pole star The latitudes derived from these observations agree capitally *inter se* The Pundit was thoroughly practised in the method of taking latitudes, and as his determinations of many well-known points, such as Bareilly, Moradabad, &c, have proved to be correct with only a pair of observations, there can be no doubt about accepting his latitude of Shigátze, where he took so many The Pundit followed the same river as Turner for 50 miles between Gyangze and Shigátze They agree in making the bearing between those places 62° west of north. The bends of the river as given by them agree in a general way, but the distance by Turner is 39 miles, and by the Pundit 46 miles As the former appears to have only estimated his distances by guess, while the latter paced them carefully, the result by the Pundit has been adopted as the most correct

In a route-survey, where bearings, distances and latitudes only are available, it is obvious that a route running meridianally is the most easily checked Unfortunately, in this route-survey, the only part that runs very favorably is that from Kathmandû to Tadúm, where there is a difference of latitude of 118′ to a difference of longitude of only 75′ The length of the pace derived from the difference of latitude is 2 6074 feet, or 31 inches. The remainder of the route from the Mansarowar to Gyangze runs so nearly east and west that the differences of latitudes between the various points are too small to give a reliable value for the pace, but, as far as they go, these differences indicate a longer pace than that derived from Kathmandû to Tadúm The direction of the route not being favorable for determining the pace from the latitudes, recourse has been had to the known differences of longitude between Kumaon, Kathmandû and Gyangze, derived as above The difference of longitude between Kathmandû and Kumaon makes the length of the Pundit's pace 2 53 feet, or 30 inches. The difference between

finally determine the longitude of Kathmandû in 1857, when they received permission to use their instruments in the Nepal valley The longitude might have been determined with indisputable accuracy by the simple expedient of observing the azimuth of one or more of the G T S peaks north of Kathmandû The Messrs Schlagintweit state that they saw these peaks, and recognized them as those fixed by the G T Survey, it is, consequently, all the more difficult to imagine why this great opportunity was lost Their longitude of Kathmandû was determined by a chronometer, but as the time depends upon a single day's set of altitudes taken too near to the meridian, it cannot be accepted as conclusive, but, as far as their observations can be relied on, they tend to confirm the longitude* adopted above, viz, 85° 17′ 45″

The longitudes of the points in Kumaon have been derived from the Stracheys' map †, and are known from the adjacent G T S peaks to be correct within a very small limit The longitude of Gyangze-jong (or Jhansû-jong) has been taken from Turner's survey of the road from Bhootan to Tibet, made in 1783 Turner's longitude of the Chumulárí peak is 89° 18′, the G T S longitude being 89° 18′ 43″ This coincidence no doubt is fortuitous, as there is an error of 11′ in the longitude of the origin of his survey, however it may have happened, Turner's longitudes up to Chumulárí seem to be correct, for Captain Godwin-Austen, whilst surveying in Bhootan, ascertained that the village of Phárí, close to the Chumulárí, is very nearly in the longitude ascribed to it by Turner Turner moreover puts Tassísudon in longitude 89° 41′, and Captain Austen in 89° 40′

It may, consequently, be assumed that the longitude of Turner's route near the Chumulárí peak is nearly correct From the neighbourhood of the Chumulárí to Jhansû-jong, Turner's route runs nearly due north, and therefore any error in his estimate of distances would have a very small effect on the longitude This is fortunate, as it is not known how Turner measured his distances, though he specially states that he took bearings with a compass The distance between Chumulárí and Jhansû-jong is only about 80 miles, and as the bearing is so northerly (viz, 20° E of N), it may be concluded that any error in the distance has had but small effect on the longitude The longitude of Gyangze has therefore been assumed from Turner to be 89° 31′ Turner observed the latitude at Tashil-

* The Schlagintweit's longitude of Kathmandû in terms of the G T Survey is 85° 15′ 34″.

† Compiled in the Surveyor General's Office, Calcutta, April 1850.

umbo (Shigátze), and made it 29° 4′ 20″, the Pundit makes it 29° 16′ 32″ Turner's latitude of Chumuláří is 28° 5′, the G T S latitude is 27° 50′ Turner very possibly was not accustomed to take latitudes, and as the Surveyor (Lieutenant S Davis) sent with him was not allowed to go beyond Tassísudon, it is not to be wondered that there are differences in his latitudes The comparison of several latitudes now well-known, tend to show that the semi-diameter of the sun may have been omitted by Turner, as his observations were to the sun only

The Pundit's observations at Shigátze extend over many days, and include thirteen observations to the sun and a variety of southern stars, as well as to the pole star The latitudes derived from these observations agree capitally *inter se* The Pundit was thoroughly practised in the method of taking latitudes, and as his determinations of many well-known points, such as Bareilly, Moradabad, &c, have proved to be correct with only a pair of observations, there can be no doubt about accepting his latitude of Shigátze, where he took so many The Pundit followed the same river as Turner for 50 miles between Gyangze and Shigátze They agree in making the bearing between those places 62° west of north. The bends of the river as given by them agree in a general way, but the distance by Turner is 39 miles, and by the Pundit 46 miles As the former appears to have only estimated his distances by guess, while the latter paced them carefully, the result by the Pundit has been adopted as the most correct

In a route-survey, where bearings, distances and latitudes only are available, it is obvious that a route running meridianally is the most easily checked Unfortunately, in this route-survey, the only part that runs very favorably is that from Kathmandu to Tadúm, where there is a difference of latitude of 118′ to a difference of longitude of only 75′. The length of the pace derived from the difference of latitude is 2 6074 feet, or 31 inches. The remainder of the route from the Mansarowar to Gyangze runs so nearly east and west that the differences of latitudes between the various points are too small to give a reliable value for the pace, but, as far as they go, these differences indicate a longer pace than that derived from Kathmandû to Tadúm The direction of the route not being favorable for determining the pace from the latitudes, recourse has been had to the known differences of longitude between Kumaon, Kathmandû and Gyangze, derived as above The difference of longitude between Kathmandû and Kumaon makes the length of the Pundit's pace 2 53 feet, or 30 inches. The difference between

Kathmandû and Gyangze makes the length of the Pundit's pace to be 2.75 feet, or 33 inches.

The route between Kathmandû and Kumaon taken by the Pundit is the worst part of the whole of his route. It crosses the Himalayas twice, and also several high passes, and the road on the Cis-Himalayan side is particularly rough and rocky, with great ascents and descents. It was consequently to be expected that his pace would be somewhat shorter than on the route between Tadúm and Gyangze, which runs the whole distance by the easiest slopes possible, without crossing a single steep pass. The Pundit's pace, as derived from his own difference of latitude between Kathmandû and Tadúm, is 2.61 feet, or 31 inches. If this pace were adopted between Kathmandû and Kumaon, the difference of longitude between the two would be only 13′ larger than the assumed difference, or in 320′ (5° 20′) only a discrepancy at the rate of 4 per cent. If this same pace were used between Tadúm and Gyangze the difference of longitude would be 17′ less than the assumed difference, viz., 328′ (5° 28′), or a discrepancy at the rate of only 5 per cent.

The two lengths of the pace, derived from the difference of longitude, agreeing so closely with that derived from the Pundit's difference of latitude between Nepal and Tadúm, the one being slightly shorter in the roughest ground, and the other slightly longer in the easiest ground, it seems reasonable to conclude that the lengths of pace derived from the longitudes are quite in accordance with all that is known of the route. The Pundit was practised to walk 2,000 paces in a mile, or say a pace of $31\frac{1}{2}$ inches, and he has certainly adhered very closely to it. From Gyangze to Lhasa the road is very similar to that between Tadúm and Gyangze, and the same value of pace, viz., 2.74* has been used. This gives a difference of longitude of 1° 28′ 7″. The Pundit's latitude of Lhasa is derived from twenty separate observations to the sun and stars. It is probably within half a minute of the correct value. From the above it is concluded that Lhasa is in north latitude 29° 39′ 17″, and east longitude 90° 59′ 43″.

Between the Mansarowar lake and Lhasa, the Pundit travelled by the great road called the Jong-lam† (or Whor-lam), by means of which the Chinese officials keep up their communications for 800 miles along the top

* The direction of the road between Piahtejong and Lhasa is rather more favourable for making use of the Pundit's latitudes. If used, they would give a pace of 2.86 feet, a proof that the pace was longer than between Tadúm and Kathmandû. This pace would put Lhasa in longitude 91° 3′ 36″.

† Lam means road in the Tibetan language.

of the Himalayan range from Lhasa, north of Assam, to Gartokh, north-east of Simla. A separate memorandum is given hereafter as to the stages, &c., on this extraordinary road. Starting from Gartokh on the Indus, at 15,500 feet above the sea, the road crosses the Kailas range by a very high pass, descends to about 15,000 feet in Nari Khorsum, the upper basin of the Sutlej, and then coasting along the Rakas Tâl, the Mansarowar, and another long lake, rises gradually to the Marham-la pass, the watershed between the Sutlej and Brahmaputra, 15,500 feet above the sea. From the Marham-la the road descends gradually, following close to the north of the main source of the Brahmaputra, and within sight of the gigantic glaciers, which give rise to that great river. At about 50 miles from its source the road is for the first time actually on the river, but from that point to Tadúm it adheres very closely to the left bank. Just before reaching Tadúm the road crosses a great tributary, little inferior to the main river itself. The Tadúm monastery is about 14,200 feet above the sea.

From Tadúm, the road follows down the Brahmaputra, sometimes close to it, sometimes several miles from it, but at 80 miles east of Tadúm the road leaves the river, and crossing some higher ground, descends into the valley of the Raka Sangpo river, which is a great tributary of the Brahmaputra, leaving the Rakas valley, the road crosses over the mountains, and again reaches the Brahmaputra at about 180 miles below Tadúm. About 16 miles lower the road changes from the left bank to the right bank, travellers having to cross the great river by ferry-boats near the town of Janglache. Below Janglache, the road follows the river closely to a little below its junction with the Raka Sangpo. From that point the road runs some 10 miles south of the river, crossing the mountains to the large town of Shigátze, 11,800 feet above the sea. From Shigátze the road runs considerably south of the river, it ascends the Penanangchú river, and crossing the Kharola pass, 17,000 feet above the sea, descends into the basin of the Yamdokcho lake. For two long stages the road runs along this great lake, which is 13,700 feet above the sea, then rising sharply, crosses the lofty Khamba-la pass, and descends to the Brahmaputra again, now only 11,400 feet above the sea. Following the great river for one stage more, the road (which has hitherto been running from west to east) here leaves the Brahmaputra, and ascends its tributary, the Kichu Sangpo, in a north easterly direction for three stages more to Lhasa, which is 11,700 feet above the sea. The total distance is about 800 miles from Gartokh to Lhasa.

This long line of road is generally well-defined, though it is not a made road, in the European sense of the word. The natural slopes over which the road is carried are are however wonderfully easy. The Tibetans have, as a rule, simply had to clear way the loose stones, and only in three or four places, for a few miles, has anything in the way of making a road been necessary.

In many parts there appears to have been considerable danger of losing the road in the open stretches of the table-land, the whole surface looking very much like a road; but this danger is guarded against by the frequent erection of piles of stones, surmounted with flags on sticks, &c. These piles, called lapcha by the Tibetans, were found exceedingly handy for the survey; the quick eye of the Pundit generally caught the forward pile, and even if he did not, he was sure to see the one behind, and in this way generally secured a capital object on which to take his compass bearings. The Tibetans look upon these piles partly as guide posts, and partly as objects of veneration; travellers generally contribute a stone to them as they pass, or if very devout and generous, add a piece of rag; consequently, on a well-used road these piles grow to a great size, and form conspicuous objects in the landscape. Over the table-land the road is broad and wide enough to allow several travellers to go abreast; in the rougher portions, the road generally consists of two or three narrow paths, the width worn by horses, yâks, men, &c., following one another. In two or three places these dwindle down to a single track, but are always passable by a horseman, and, indeed, only in one place, near Puncholing, is there any difficulty about laden animals. A man on horseback need never dismount between Lhasa and Gartokh, except to cross the rivers.

The road is, in fact, a wonderfully well-maintained one, considering the very elevated and desolate mountains over which it is carried. Between Lhasa and Gartokh there are 22 staging places, called Tarjums, where the baggage animals are changed. These Tarjums are from 20 to 70 miles apart; at each, shelter is to be had, and efficient arrangements are organized for forwarding officials and messengers. The Tarjums generally consist of a house, or houses, made with sun-dried bricks. The larger Tarjums are capable of holding 150 to 200 men at a time, but some of the smaller can only hold a dozen people; in the latter case, further accommodation is provided by tents. At six Tarjums, tents only are forthcoming. Each Tarjum is in charge of an official, called Tarjumpá, who is obliged to have

horses, yâks, and coolies in attendance whenever notice is received of the approach of a Lhasa official From ten to fifteen horses, and as many men, are always in attendence night and day Horses and beasts of burden (yâks in the higher ground, donkeys in the lower) are forthcoming in great numbers when required, they are supplied by the nomadic tribes, whose camps are pitched near the halting houses

Though the iron rule of the Lhasa authorities keeps this high road in order, the difficulties and hardships of the Pundit's march along it cannot be fully realized, without bearing in mind the great elevation at which the road is carried Between the Mansarowar lake and the Tadúm monastery, the average height of the road above the sea must be over 15,000 feet, or about the height of Mont Blanc Between Tadum and Lhasa its average height is 13,500 feet, and only for one stage does the road descend so low as 11,000 feet, whilst on several passes it rises to more than 16,000 feet above the sea Ordinary travellers with laden animals make two to five marches between the staging houses, and only special messengers go from one staging-house to another without halting Between the staging-houses, the Pundit had to sleep in a rude tent that freely admitted the biting Tibetan wind, and on some occasions he had to sleep in the open air

Bearing in mind that the greater part of this march was made in mid-winter, it will be allowed that the Pundit has performed a feat of which a native of Hindustan, or indeed of any country, may well be proud Notwithstanding the desolate track they crossed, the camp was not altogether without creature comforts The yâks and donkies carried a good supply of ordinary necessaries, such as grain, barley-meal, tea, butter, &c., and sheep and goats were generally procurable at the halting places A never failing supply of fuel, though not of the pleasantest kind, was generally forthcoming from the *argols* or dried dung of the baggage animals, each camp being supposed to leave behind at least as many argols as it burns. At most of the halting places there is generally a very large accumulation

Between the Mansarowar and Sarkájong, nothing in the shape of spirits was to be had, but to the eastward of the latter place a liquor made from barley could generally be got in every village This liquor, called *chung*, varies in strength, according to the season of the year, being in summer something like sour beer, and in the winter, approximating closely in taste and strength to the strongest of smoked whiskey. The good-natured Tibetans are constantly brewing chung, and they never begrudge anyone a

drink Thirsty travellers, on reaching a village, soon find out where a fresh brew has been made, their drinking cups are always handy in their belts, and they seldom fail to get them filled at least once The Pundit stoutly denied that this custom tended to drunkenness among his Tibetan friends, and it must be allowed that in Ladák, where the same custom prevails, the people never appeared to be much the worse for it, guides had however to be rather closely watched, if the march took them through many villages, as they seldom failed to pull out their cup at each one

A good deal of fruit is said to be produced on the banks of the Brahmaputra, between Shigátze and Chushul The Pundit only saw it in a dried state

When marching along the great road, the Pundit and his companions rose very early, before starting, they sometimes made a brew* of tea, and another brew was always made about the middle of the march, or a mess of stirabout (*suttoo*)† was made in their cups, with barley-meal and water On arriving at the end of a march, they generally had some more tea at once, to stave off the cravings of hunger, until something more substantial was got ready, in the shape of cakes and meat, if the latter was available Their marches generally occupied them from dawn till 2 or 3 P M, but sometimes they did not reach their camping ground till quite late in the evening. On the march they were often passed and met by special messengers, riding along as hard as they could go The Pundit said these men always looked haggard and worn They have to ride the whole distance continuously, without stopping either by night or day, except to eat food and change horses In order to make sure that they never take off their clothes, the breast fastening of their over-coat is sealed, and no one is allowed to break the seal, except the official to whom the messenger is sent The Pundit says he saw several of the messengers arrive at the end of their 800 miles ride Their faces were cracked, their eyes blood-shot and sunken, and their bodies eaten by lice into large raws, the latter they attributed to not being allowed to take off their clothes

It is difficult to imagine why the Lhasa authorities are so very particular as to the rapid transmission of official messages, but it seems to be a principle that is acted on throughout the Chinese empire, as one of the means of Government. Ordinary letters have a feather attached to them,

* The Tibetans stew their tea with water, meal and butter, the tea leaves are always eaten.

† A Tibetan always carries meal with him, and makes suttoo whenever he feels hungry.

and this simple addition is sufficient to carry a letter from Lhasa to Gartokh, 800 miles, in little over thirty days A messenger arriving at a village with such a letter is at once relieved by another, who takes it on to the next village This system was frequently made use of by the Surveyors in Ladák and Little Tibet, and it generally answered well

If any very special message is in preparation, and if time permits, an ordinary messenger is sent ahead to give notice Food is then kept ready, and the special messenger only remains at each staging-house long enough to eat his food, and then starts again on a fresh horse He rides on, day and night, as fast as the horses can carry him The road throughout can be ridden over at night, if there is no moon, the bright starlight of Tibet* gives sufficient light Tibet is rarely troubled by dark nights, but, in case it should be cloudy, or that a horse should break down, two mounted men always accompany the messenger These men are changed at every stage, and are thoroughly acquainted with their own piece of road Each of these two men has, at least, two spare horses attached behind the horse he is mounted If any horse gets tired, it is changed at once, and left on the road, to be picked up on the return of the men to their own homes By this means, the messenger makes great progress where the road is good, and is never stopped altogether, even in the rougher portion A special messenger does the 800 miles in twenty-two days on the average, occasionally in two or three days less, but only on very urgent occasions The Pundit made fifty-one marches between Lhasa and the Mansarowar lake, and, his brother makes out the remaining distance to Gartokh seven marches more, or, in all, fifty-eight marches The Pundit found very few of the marches short, while a great many were very long and tedious

Little idea of the general aspect of the country which the road traversed could be given by the Pundit

From the Mansarowar lake to Tadúm (140 miles) glaciers seem always to have been visible to the south, but nothing very high was seen to the north, for the next 70 miles, the mountains north and south seem to have been lower, but, further eastward, a very high snowy range was visible to the north†, running for 120 miles parallel to the Raka Sangpo river From Janglache to Gyangze, the Pundit seems to have seen nothing high,

* The starlight in Tibet, as in all very elevated regions, is particularly bright

† With a very high peak at its western extremity called Harklang. A very high peak was also noticed to the south between the Raka and Brahmaputra valleys.

but he notices a very large glacier between the Penanang valley and the Yamdokcho lake

From the lofty Khamba-la pass the Pundit got a capital view Looking south, he could see over the island in the Yamdokcho lake, and made out a very high range to the south of the lake, the mountains to the east of the lake did not appear to be quite so high Looking north, the Pundit had a clear view over the Brahmaputra, but all the mountains in that direction were, comparatively speaking, low, and in no way remarkable

About Lhasa no very high mountains were seen, and those visible appeared to be all about the same altitude Hardly any snow was visible from the city, even in winter * From the Mansarowar to Ralung, 400 miles, there were no villages, and no cultivation of any kind The mountains had a very desolate appearance, but still numerous large camps of black tents, and thousands of sheep, goats, and yâks were seen The fact being that the mountain sides, though looking so arid and brown, do produce a very nourishing coarse grass

To the eastward of Ralung, cultivation and trees were seen every day near the villages Near the Yamdokcho lake, the lower mountains seem to have had a better covering of grass The Pundit mentions the island in the Yamdokcho as being very well grassed up to the summit, which must be 16 or 17,000 feet above the sea This extra amount of grass may be due to a larger fall of rain, as the Pundit was informed that the rains were heavy during July and August

As a rule, the Pundit's view from the road does not seem to have been very extensive, for although the mountains on either side were comparatively low, they generally hid the distant ranges

The only geological fact elicited is that the low range to the east of the Lhasa river was composed of sandstone According to the Pundit, this sandstone was very like that of the Siwálik range at the southern foot of the Himalayas

The probability of this is perhaps increased by the fact that fossil bones are plentiful in the Lhasa district. They are supposed to possess great healing properties when applied to wounds, &c., in a powdered state The Pundit saw quantities of fossils exposed for sale in the Lhasa bazar The people there call them Dúg-rúpa, or lightning bones One fossil particularly struck the Pundit, it consisted of a skull which was about $2\frac{1}{2}$ feet long, and $1\frac{1}{2}$ feet broad The jaws were elongated, but the points had been broken off.

The mountains crossed were generally rounded with easy slopes The roundness of those on the Yamdokcho island seems to have been very remarkable, this general roundness and easiness of slope probably points to former glacier or ice action

Besides the Yamdokcho, a good many smaller lakes were seen, and two much larger ones were heard of. Those seen by the Pundit were all about 14,000 feet above the sea There are hardly any lakes in the lower Himalayas, the few that exist being all at, or below, 6,000 feet, but from about 14,000 to 15,000 feet lakes and tarns are particularly numerous * This may be another evidence of former ice action

Whilst the Pundit was at Shigátze and Lhasa, he took a series of thermometer observations to determine the temperature of the air During November, at Shigátze, the thermometer always fell during the night below the freezing point, even inside a house The lowest temperature recorded was 25°, and during the day the temperature hardly ever rose to 50° At Lhasa, in February, the thermometer generally fell below 32° during the night, and the lowest observed temperature was† 26°, during the day it seldom rose to 45° During the whole time the Pundit was in the Lhasa territory, from September to the end of June, it never rained, and snow only fell once whilst he was on the march, and twice whilst in Lhasa

The snow fall at Shigátze was said to be never more than 12 inches, but the cold in the open air must have been intense, as the water of running streams freezes if the current is not very strong A good deal of rain falls during July and August about Shigátze, and there is said to be a little lightning and thunder, but the Pundit does not recollect seeing the one or hearing the other whilst he was in the Lhasa territory The wind throughout Tibet is generally very strong on the table-lands, but at Shigátze and Lhasa, it does not seem to have been in any way remarkable The sky during the winter seems to have been generally clear

The Pundit's heights were all determined thermometrically, that is, by observing the temperature of boiling water The height of Kathmandû, thus determined, agrees very closely with that deduced from other sources, the thermometer used there, and at Muktináth, returned in safety, and

* There are no lakes known in the Himalayas higher than 16,000 feet, but possibly one of those heard of by the Pundit may turn out to be a little higher

† Inside a house

was afterwards boiled at a trigonometrical station. It was found to agree with the observations taken before the Pundit went to Kathmandu.

The Pundit took another thermometer with him to Lhasa, and, with it, all his higher points were determined. This latter was unfortunately broken near the end of the Pundit's march. There has, consequently, been no means of finding out whether it had altered in any way during the journey, nor any opportunity of testing it at known altitudes. If it had come back safely, there would have been no difficulty in having it boiled at trigonometrical stations of all heights, up to the highest visited by the Pundit. This thermometer was boiled at Almorah before the Pundit started, and with that observation as a zero, the heights of Lhasa, &c., have been computed out.

The height of Darchan, a little above the Mansarowar lake, computed out in this way, is found to be 14,489 feet above the sea. The Mansarowar lake, as derived from Captain H. Strachey's thermometrical observations, is 14,877* feet, or taking a mean between his height of the Mansarowar and Rakas Tal lakes, it is about 15,000 feet, a result 4 or 500 feet higher than the Pundit's height. It may consequently be concluded that the Pundit's heights are not in excess.

With reference to the spelling of the name of the capital of Tibet, Lhasa has been adopted, as that agrees best with the Pundit's pronunciation of of the word. He says the word, means God's abode, from Lha, a God, and Sa, a place.

It may be remarked that more bearings to distant peaks would have been a great addition to the Pundit's route-survey, but the recognizing of distant peaks from different points of view is a difficult matter, and only to be accomplished after much practice. The Pundit's next survey will, no doubt, be much improved in this respect. On the whole, the work now reported on has been well done, and the results are highly creditable to the Pundit.

* Mansarowar, 175 feet above lake, air, 46°·0 boiling point 186·0,
Rakas Tál, ,, ,, 54°·0 ,, ,, 186·0,
Petoragurh, 5,500 above sea, ,, 64°·0 ,, ,, 202·5

T. G. M.

PAYMENT FOR CANAL WATER.

THE question of the distribution and economy of water used in irrigation is one of great interest at the present time, when so many fresh irrigation projects are before the Government, and the series of papers published by the Bombay Government* contain a great variety of opinions on the subject by different officers—on which we propose to offer a few remarks

On one point only is there perfect unanimity both on the Bengal and Bombay side, that the present system of measuring the area of land irrigated, ought, whenever practicable, to be superseded by a system of measurement of water delivered

There is no doubt that the present system causes waste of water, an important matter, when the amount of water is limited, while that of land is practically unlimited, and one remedy proposed for this is, that devised by the (late) Financial Commissioner of the Punjab, and supported by the P W Secretary, which is to dispense with surface irrigation altogether, by laying out the distributaries so as to necessitate the whole of the water being lifted; the idea being, that if the people have to raise it for themselves, they will only raise what is absolutely required and so waste will be prevented But surely to create one difficulty wilfully, where none exists, for the purpose of removing another, is a very clumsy expedient for remedying the latter It is simply to waste labor, and that in a country like the Punjab, where population is sparse and labor dear By parity of reasoning, wells should be preferable to canals

The Secretary to the Punjab Government makes a proposal of his

* Papers relating to the system of periodical measurements of irrigated lands and the distribution and Economy of water

own, viz., to employ a system of intermediate reservoirs whose capacity being actually known, and which being periodically filled from the canal, would deliver an exact quantity of water by means of the minor water-courses running from them. This however would probably entail a loss of head which in most cases could not be afforded, moreover the cost of the arrangement both in first construction and subsequent clearance from silt, seems to put it out of the question, though, as regards the silt clearance, it would generally be beneficial, for in the canals in these Provinces the silt is generally pure sand and an evil to the cultivator, does not enrich his fields like the muddy silt of the Delta lands.

Besides the waste of water, the most serious disadvantage of the present system, however, appears to be, that the Canal Engineers have so much of their time taken up by settling water disputes and investigating questions which more properly belong to the civil officials. It is true they no longer actually collect the Canal Revenues as they did in these provinces until very recently, but it is upon their measurements and calculations that the collection is made, and it certainly seems no more a part of their proper work as Engineers, than questions of traffic are of that of the Railway Engineer.

The difficulty about a system of water measurement, is, as is well known, in the difficulty of devising a satisfactory water module—that is, one which shall discharge a constant quantity of water under a varying head of pressure. Several modules have, it is true been invented, which work satisfactorily, such as the Italian module which has been in use for very many years, or Carroll's module, which was described in No. CXLV. of these papers. But both these, as well as others, require a fall at the head of the delivery channel of at least 12 inches, and such a fall is not always procurable, nevertheless, it seems strange that they are not used wherever there *is* an available fall, and even where the employment of a module is impracticable, there does not seem any insuperable objection to an approximate measurement of the quantity actually discharged by periodical observations of the gauge. There is no

doubt that the observer would be liable to be tampered with, but such observations would always be checked by others, so that the cheating if carried beyond certain small limits would not be done with impunity, and we fully endorse Colonel Fife's opinion that any excessive accuracy of measurement is not necessary

"It has often seemed to me that since the people are allowed to use the water for perhaps one-tenth or one-twentieth part of its actual value to them, an apparatus which will even approximately measure the volume of water is all that is absolutely necessary What is principally wanted is an apparatus which will measure water even approximately, and which at the same time shall be as secure as possible from any interference whatsoever, whether by the canal establishment or by the cultivator

"It is understood by us on this side of India that the main cause of the failure of the module, is the collection of silt in the intermediate chamber, but if this causes no more inaccuracy than one-fourth of the volume of water discharged by the apparatus, I should not be disposed to condemn it We are already aware how very unequally natives divide water among themselves, and yet how well contented they remain Some rough measurement is adopted which is really far worse than inaccurate as far as measurement goes, but it removes the grounds of the quarrel sufficiently to prevent constant altercation, and those who fought for every drop of water before are at length satisfied with a very unequal division"

Colonel Fife describes two kinds of simple apparatus for measurement, which it is proposed to try in the Deccan, and which seem likely to succeed

"One consists of a simple slit in a masonry wall at the side of the canal, through which the water discharges itself into a wide trough, the level of which can never vary, owing to the largeness of its perimeter over which the water spills The depth of such a slit depends upon its position on the canal If near the head of the canal, its depth will not be nearly equal to the depth of the canal, but if it is at the tail, it will be the full depth of the canal The width of such a slit or notch is to be decided upon after the proba-

ble quantity of water required has been ascertained This plan must cause a loss of head equal to the depth of the slit or notch, but it might generally be applied where the loss of head could be afforded, and it possesses this great advantage, that it may be so placed as to always draw off about the same proportion of water to the whole supply in the canal, whether that be large or small. Within considerable limits it would be self-regulating, and so simple in construction as to be fully comprehended by every native in the country It is not pretended that the arrangement is a perfect one, but merely that it is sufficiently accurate in its working, and secure from tampering, as to give grounds for hoping that it will give universal satisfaction.

"The other apparatus which has been discussed is merely a low, but wide, weir, thrown across the distributing channel The weir is to be divided off into lengths proportional to the demand for water by each village or each cultivator, and the shares of water thus divided are to be led off to the fields by separate small channels commencing from the weir. The length of the weir will be regulated by the head of water or loss of head which can be afforded It is only necessary that there should be a clear over-fall, or in other words that the weir should not be a "sunken" or "submerged" one, a fall of 2 or 3 inches would suffice. To prevent any accumulation of silt taking place on the upper side of the weir and affecting the discharge over the different portions of the length, the floor of the canal where it approaches the weir is to be of masonry, and regularly swept either by the canal establishment or the villagers, if they will agree to attend to the apparatus This arrangement like the other one is simple, and would be understood by the cultivators, at the same time that it cannot be tampered with without discovery The villagers, if they had the management of it, would keep a watch over each other The plan seems to us to be well suited to the distribution of water in small branch channels"

But what we would suggest is that the whole conditions of the question should be fairly set forth by Government and that a liberal reward should be offered to any Engineer who will invent a practical

module, the reward not to be paid until the apparatus has been actually at work for some time. We cannot but think that if the efforts of the many distinguished and ingenious engineers of the day, in India, England, and the Continent were thus stimulated, the result would be successful—at any rate it seems well worth a trial.

One change in the present system of payment might certainly be made without any difficulty. At present many of the cultivators wait till the last moment before agreeing to take water for their crops, in the hope that a timely fall of rain will enable them to dispense with it for that harvest at least. Now when Government has gone to an enormous expense in constructing a great irrigation work, it is preposterous that its financial success should be dependent on such a contingency as this. What might fairly and justly be done would be to charge the present water rates to all those who agreed to take water before a certain date, while later applicants should be obliged to pay an extra per centage, increasing according to the lateness of the date at which their application was received. The justice of such a step is sufficiently obvious, and there seems nothing to prevent its being carried out. It would also evidently lead to the system of contract for a fixed term of years being everywhere adopted, and there would be some stability in the canal revenue and far less trouble to the canal establishment.

But that should be regarded as only a stepping stone to the desirable consummation of the sale of the water itself by measurement, to that we are convinced the attention of the Irrigation Department should be steadily directed, and every measure should be regarded as imperfect that does not tend to that end. There is no reason whatever for introducing it everywhere at once, but on the other hand there is no reason for waiting until a theoretically perfect system shall be devised. Any method that is approximately correct is better than the present one, which to every one but the Canal Engineer, who has grown accustomed to it and is in a manner pledged to it by the traditions of the Department, is unscientific, clumsy, and fraught with grave practical objections.

J. G. M.

No CXC

THE NEW LAHORE CHURCH.

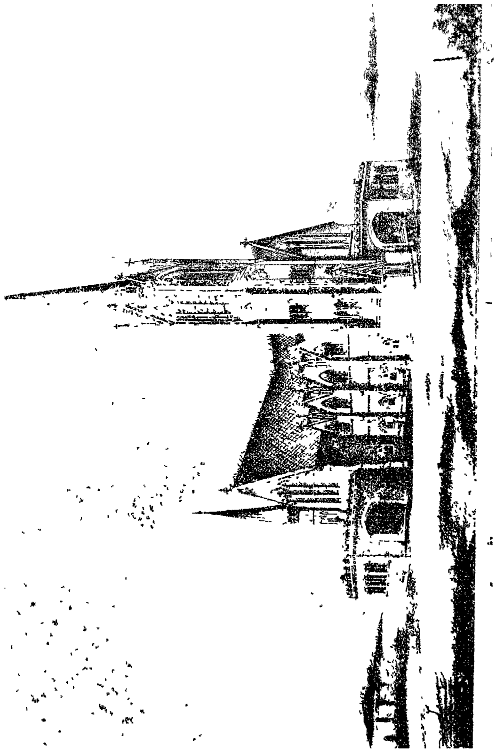
E. J MARTIN, C E, *Architect*

DESIGNS were invited last year for the New Church, which it is proposed to erect in the Civil station of Lahore The building was to be designed to hold 600 persons, and the total cost was not to exceed Rs 80,000 Nine designs in all were submitted, and the first prize of Rs 500 was gained by Mr E Martin, Executive Engineer of Delhi

The following are the names of the gentlemen who composed the Committee of selection —

A A Roberts, Esq, C B, C S I —C U Aitchison, Esq., C S — Colonel Maclagan, R E —Dr. Smith —Colonel Crofton, R E —Rev J K Stuart, M A —W Kirke, Esq —J Lincoln, Esq —W Oliver, Esq —H Gunn, Esq

Description of the premiated design —I have adopted Gothic as being the style of all others best suited for an ecclesiastical building, the period chosen being that of the renaissance, between the Early English and the Decorated, or the time embraced between the middle of the 13th and 14th centuries, when, after long ages of darkness and falsehood, constructive and artistic truth began to appear in the freshness and vigour of a revised system In this period, instinct with such glorious associations in connection with architectural art, and hallowed by so many sacred memories, our finest and most tastefully designed churches were erected, many of which still exist, as examples to us, and memorials of the perseverance, energy, and unexampled talent and true appreciation of what was beautiful, possessed by their authors.



A reference to the plans will show that I have endeavoured to design all the requisites for a church, without the introduction of unnecessary or profuse ornamentation, which looks incongruous and leads to considerable additional and useless expenditure

As required by the advertised conditions, the building is calculated to accommodate 600 persons, allowing each about 2 feet 4 inches sitting room This allowance is ample, and is 9 inches (or half as much again) in excess of what is generally allotted to each adult in English churches

In order to ensure coolness in the interior of the building, I have placed all the sittings in the nave and transepts of the church only, leaving the side aisles vacant, the other adjuncts for obtaining coolness and thorough ventilation will be noticed further on

The design is for a cruciform church with transepts of the same width and height as the nave, the proportions of length to breadth in every part, being carefully deduced from some of the best known examples

I have avoided an error commonly committed in the construction of Churches in India, viz, that of placing the windows which light the church, on a low level, and thus getting a disagreeable glare directly in the face of the congregation, besides generating heat where coolness is most needed I have placed the windows which light the nave in the upper part of the aisle walls, and thus, all light will be admitted from the top, and the objectionable glare before mentioned, altogether avoided, and as all the windows are to be glazed with stained and colored glass, the subdued light which is so appropriate to a religious edifice, will be obtained.

It is necessary, however, to admit air at a low level, and this important point I have not overlooked. Small openings, each measuring 4 feet wide and 3 feet high, have been introduced in the lower part of the outer walls.* These openings are to have a stone carved screen, of an appropriate design, fixed at the inner side of the wall, the outer portion of the opening being furnished with two-leaved shutters, of Gothic pattern, made to open outwards

These lower perforated windows are intended to be rendered useful in a variety of ways In the cold season, the shutters can be opened and the cool air allowed to circulate through the building, while in the hot weather, they can be furnished with khus tatties, at the weather

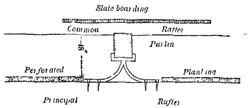
* I have borrowed this idea from Mr C Campbell, who has introduced similar openings in St Stephen's Church at Delhi, a very pretty building, and a good specimen of its own peculiar style

side or that from which the hot winds may be blowing, moreover, as many thermantidotes as may be needed to cool the church, can be placed at these openings and worked from the outside

I propose to build the walls of the church hollow, with a sufficient number of through stones (or bricks specially moulded for the purpose), extending the full thickness of the walls, to secure efficient bond, a free circulation of air will thus take place within the walls.

A cool roof in India is a consummation much to be desired, and with a view to securing this desideratum, I have designed a double roof with a space of 18 inches (if desirable this space can be increased) between the outer and inner skin

A strong perforated, boarded sheeting is laid on the backs of the principal rafters, and the slating is also to be secured to planking nailed to the common rafters, a space of at least 18 inches being left between the upper and lower planking In order to obtain this depth for the circulation of air in the roof, I intend to elevate the purlin on an iron spur (as per sketch in margin), securely screwed to the principal rafter If deemed advisable, the space between the two lines of boarding might be filled with charcoal (which is the lightest and best non-conductor of heat, that could be used for the purpose) leaving room for ventiducts to carry off vitiated air from the church



These openings would be in continuation of the apertures placed in the walls (*see* transverse section) for the escape of vitiated air, which, it will be observed, is finally carried off through the ridge ventilators shown in the drawings

I am of opinion that the simple expedients above adverted to, will be sufficient to secure a cool temperature and thorough ventilation

If practicable, I would recommend the use of thermantidotes on the exhausting, instead of the forcing, principle, but, I imagine, it would be almost impossible to keep all the doors of a church closed throughout the entire service.

With tatties and thermantidotes, worked in the lower openings

shown on the plans, punkahs would not be desirable or necessary, they are objectionable and unsightly, and might, with advantage, be dispensed with altogether

I have provided a vestry at the south side, with shelved lockers for the church records

There are no galleries, save a loft for the organ and choir, which I have placed in the north transept as being the coolest in the hot weather This organ loft is reached by a spiral staircase within a turret in one angle of the transept The entrance to the stairs opens into the carriage porch, and the gallery can be reached by the persons belonging to the choir, without its being necessary for them to pass through the church

Spacious carriage porches have been placed at the three principal entrances

The end bay in the south aisle, near the west or main entrance, I have allotted for the baptistry, which I opine should be an important and distinctive feature in every church, with this view I propose to have it enclosed by a carved Gothic screen of appropriate design

The large windows in the different gables should be filled with subjects illustrative of the principal passages in Scripture history, the remaining windows might be of colored glass, with medallions, shields and quarterfoils occasionally introduced nothing but stained and colored glass should be used in all the windows

I have designed a light and plain tower and spire, in which I purpose to place a clock and a peal of bells.

The whole of the walls will be constructed of brickwork. I propose to have the body of the work of plain red bricks, interspersed with light and dark-toned bands of colored brick, purposely selected of various tints, contrasting with the color of the main portions of the fronts, all the shafts, caps and bases of pillars, crockets, finials, &c., being of sandstone

The passages between the sittings should be laid with encaustic tiles of a suitable pattern, these tiles are very little more expensive than a sandstone floor, they are quite as durable, and much better adapted for church floors

The pulpit, reading desk and reredos are to be of sandstone, or a combination of sandstone and marble.

I propose to light the church with bronzed coronæ, and polished brass bracket lamps of ecclesiastical pattern, as described in the annexed specification

SPECIFICATION

Foundations —A layer of concrete 18 inches deep and of the description generally used at Lahore, to be placed in the bottom of the foundations, to be thoroughly watered and rammed in 6-inch courses

Over the concrete the foundations to be built of the best description of pucka masonry, well and securely bonded

Masonry in superstructure —The superstructure to be of the best brick masonry in lime mortar, to be built to the shape and dimensions shown on the drawings, and to be strengthened with through bond stones, or bricks specially moulded for the purpose The masonry to be carried up at a uniform level, and every course to be carefully levelled, and the faces of the walls to be truly vertical The bricks to be laid with close joints in finely tempered mortar of the description found to be the best at Lahore

Colored bricks (if procurable) to be laid in voussoirs and bands as shown on the elevations.

The tracery of windows, mullions, bosses, kneelers, apex, crosses, &c , to be carefully cut in sandstone, or any other suitable description of stone procurable, to be correctly shaped and neatly finished Connections with the brick-work to be made with fine joints, and all projections, over which water will drip, to be throated underneath

Plastering —The walls to be lime plastered internally and finished in imitation of ashlar

Flooring —The passages between the sittings and other portions shown on the ground plan, to be laid with Minton's tiles, over a bed of concrete evenly laid to receive them, the tiles to be of a suitable pattern and to be laid perfectly level and with the finest possible joints The remainder of the floor to be terraced and finished with a coat of fine plaster well tapped and consolidated.

The steps in the carriage porches to be of 8-inch flagging over brick-work.

Roofing to be 24 × 12-inch slates (Duchesses) of the best quality, each slate to be secured with 3 copper nails, the nail holes to be drilled

and counter-sunk to receive the heads of the nails, to be laid with a 4-inch cover or overlap clear of nail holes, on 1 inch thick deodar boarding nailed diagonally to $4\frac{1}{2} \times 2\frac{1}{2}$-inch common rafters, at central distances of 18 inches apart

The roof timbers to be framed as shown in sections, the curved ribs to be in two thicknesses bolted together, the several pieces breaking joint All the framing to be diamond chamfered, and strengthened with wrought iron straps and stirrups where needed, all the woodwork in the roofs to receive 3 coats of the best copal varnish, and the iron-work to be lacquered

All timbers used in the construction of the church, save for furniture, chancel rail, &c, to be of the best seasoned deodar, free from all imperfections, to be straightly and smoothly sawn, and to be finished to the exact dimensions given on the drawings.

All hips, ridges and vallies to be protected and rendered water-tight with zinc or lead flashings and sheeting, properly fixed

Furniture—The Seats to be of deodar framing, elbows 3 inches, and back framing $2\frac{1}{2}$ inches, thick, with $\frac{3}{4}$-inch thick panels. The framing to be stop chamfered, and a book board 6 inches wide and $\frac{1}{2}$-inch thick, with a retaining strip to prevent the books from slipping off, to be attached to each seat.

The Pulpit, Reading Desk, and Reredos, to be of sand stone, as per detailed drawings, which will be furnished hereafter, with marble panels, crosses, screens, &c

The Lectern to be of carved toon-wood, varnished.

The Font to be of white marble, mounted on two sand stone steps, to have an appropriate canopy of toon or seeshum wood, mounted with brass, and to be enclosed in a baptistry, the screen of which will be of carved and traceried toon wood, varnished

Doors to be $2\frac{1}{2}$-inch deodar framing, stop chamfered and sheeted with $1\frac{1}{4}$-inch deodar planking rebated and beaded. All doors to be hung with ornamental brass strap hinges, and to be varnished in 3 coats best spirit varnish.

Windows to be all lead lights, glazed with stained and colored glass One section in each lancet to be hung at the under side by pivots and made to tilt inwards, and to be strengthened with 1-inch square wrought iron saddle bars leaded into the stone mullions, copper wire to be leaded

to the sashes, to be twisted round the saddle bars, so as to prevent the windows from oscillating and keep them perfectly rigid

Altar rail and chairs to be of toon or seeshum wood properly carved and polished, the chairs and chancel stalls to be upholstered with velvet of a suitable color, the remainder of the pews to be upholstered with cloth The table cloth and altar rail cloth to be of velvet, fringed with gold lace, and to have gold embroidered fleur de-lis worked on them at proper intervals apart

Lighting —The church to be lighted by bronzed coronæ of 7 lights each, hung from transverse wrought iron bars, to be placed opposite the centre of each nave arch, two such coronæ to be hung in each transept, and two in the chancel A polished brass bracket lamp of ecclesiastical pattern to be affixed to each of the nave pillars, every bracket to be furnished with two burners and globes Similar bracket lamps to be attached to both sides of the chancel arch to light the pulpit and reading desk.

Clock —A clock as shown on the plans to be placed in the tower, with transparent dials, visible from a distance, when lighted up at night The clock to be by a good English maker, and to be constructed to work a peal of 5 bells, which will be placed above it

Crosses and finials —Every apex will be surmounted with a cross, and the spires of the main tower and stair turret, to have proper finials, the former to be furnished with an appropriate vane.

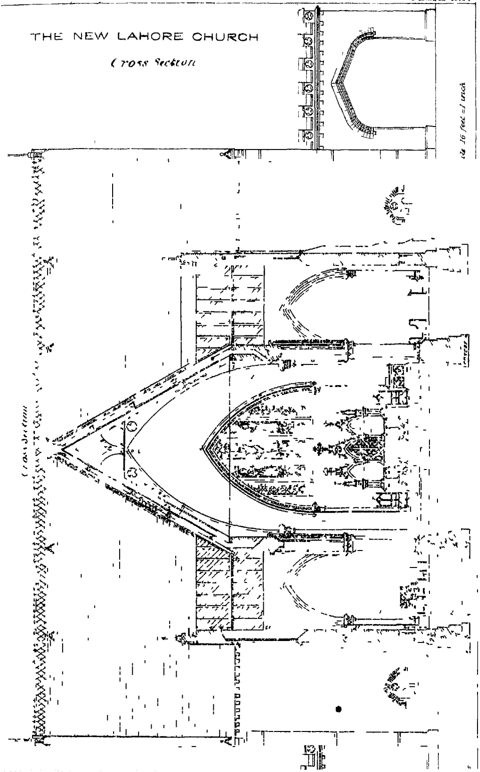
The finials and vane to be of sheet copper, gilt

ABSTRACT

c. ft		Rs
9,230	Concrete in foundations, including excavation, at Rs 16 per 100,	1,477
23,744	Pucka masonry in foundation and plinth, at Rs 20 per 100,	4,749
1,07,107	Pucka masonry in superstructure complete, at Rs 28 per 100, .	29,990
No		
4	Large stone pillars at junction of nave with transept, at Rs. 250 each, ..	1,000
2	Ditto in chancel arch, at Rs 150 each, ..	300
18	Ditto in nave, at Rs 120 each, ..	2,160
s ft		
8,743	Flooring, at Rs 40 per 100, ..	3,497
	Carried forward, ..	43,173

THE NEW LAHORE CHURCH

Cross Section



		Rs
S ft	Brought forward,	43,173
17,518	Roofing, complete, at Rs 65 each,	11,387
2,292	Flat roofing, complete, on carriage porches and floor of gallery, at Rs 40 per 100,	917
No		
9	Doors of kinds, at Rs 80 each,	720
21	Ventilating windows, complete, at Rs 30 each,	630
1	Chancel window, at Rs 1,500,	1,500
3	Gable windows in nave and transepts, at Rs 750 each,	2,250
6	Side windows in chancel and aisles, at Rs 600 each,	3,600
4	Rose windows, at Rs 250 each,	1,000
4	Couplet windows in tower, at Rs 550 each,	2,200
2	Triplet windows in tower, at Rs 200 each,	400
1	Couplet window, in do, at Rs 150,	150
1	Gilt finial on spire, at Rs 350,	350
15	Small gilt crosses on apex of aisle gables, at Rs 70 each,	1,050
1	Gilt finial, on stair turret, at Rs 100,	100
5	Crosses on apex of main gables, at Rs 60 each,	300
4	Ditto on gablets of tower, at Rs 60 each,	240
2	Stairs in tower and stair turret, at Rs, 300 each,	600
1	Font and baptistry screen, at Rs 250,	250
600	Persons' sittings, at Rs 4-8 for each person,	2,700
1	Stone pulpit, at Rs 600,	600
1	Reading desk, at Rs 200,	200
1	Lectern, at Rs 100,	100
1	Reredos and table, at Rs 1500,	1,500
2	Altar chairs, at Rs 30 each,	60
	Clock, lighting, upholstery, &c,	4,000
	Grand total of estimate, Rs,	79,977

E M.

No CXCI

PROBLEM IN PENDULUMS

To the Editor.

SIR,—I send you the solution of a problem set me a short time ago for publication in your Journal, should you think it may be of use to any of your readers

A clock was constructed so as to be started and stopped by electricity The pendulum was made to vibrate backwards and forwards, through a constant arc, being maintained in that state by an escapement which exerted a small constant force always at right angles to the pendulum. This force overcame the friction (which is considered constant) and the resistance of the air. The problem was,—To obtain a formula to represent the position of the pendulum at any time, so that if the pendulum were arrested in the course of a vibration, the exact portion of time corresponding to the broken vibration might be easily ascertained

Let θ be the angle which the pendulum makes at any time t with the vertical g gravity, l the length of the pendulum, k its radius of gyration, m the excess of the constant force of the escapement over the friction, n the resistance of the air for a unit of angular velocity exerted to retard the pendulum Then the equation of motion of the pendulum is

$$\frac{d^2\theta}{dt^2} = -\frac{gl\sin\theta}{k^2} - \frac{ml}{k^2} + \frac{nl}{k^2}\left(\frac{d\theta}{dt}\right)^2$$

in which m and n are very small quantities, the squares of which may be neglected The resistance of the air varies as the square of the velocity Also, as the arc of vibration is always small, we may neglect the square of θ, and the equation becomes

$$\frac{d^2\theta}{dt^2} = -\frac{gl}{k^2}\theta - \frac{ml}{k^2} + \frac{nl}{k^2}\left(\frac{d\theta}{dt}\right)^2$$

We shall use Lagrange's method of the variation of parameters to solve this equation —

I Suppose that there is no friction or resistance of the air, the equation is then simply

$$\frac{d^2\theta}{dt^2} = -\frac{gl}{k^2}\theta\,,\ \text{put}\ \frac{gl}{k^2} = c^2$$

$$\therefore \frac{2d\theta}{dt}\frac{d^2\theta}{dt^2} = -2c^2\theta\frac{d\theta}{dt}$$

$\therefore \left(\frac{d\theta}{dt}\right)^2 = c^2(a^2 - \theta^2)$, where a is an arbitrary constant

$\therefore c\dfrac{dt}{d\theta} = \dfrac{-1}{\sqrt{a^2-\theta^2}}$, the negative sign being taken because θ diminishes as t increases,

$\therefore ct + \beta = \cos^{-1}\dfrac{\theta}{a}$, ($\beta$ an arbitrary constant)

$\therefore \theta = a\cos(ct + \beta)$,

a is evidently half the complete arc of vibration from rest to rest

β is a constant which marks the epoch from which t is reckoned If $\theta = a$ when $t = 0$, then $\beta = 0$ and $\theta = a\cos ct$.

II Take friction and air into account then

$$\frac{d^2\theta}{dt^2} = -\frac{gl\theta}{k^2} - \frac{ml}{k^2} + \frac{nl}{k^2}\left(\frac{d\theta}{dt}\right)^2 \quad \ldots(1)$$

Lagrange's method is thus, Assume that the solution of this equation, which differs only by small quantities from the former equation, is of the same form as before, viz.,

$$\theta = \text{A}\cos(ct + \text{B}), \quad \ldots(2)$$

A and B being now, not constant, but variable functions of t, such as to make the expression satisfy the equation to be solved, And further, since there are *two* variable quantities, A and B, and only one equation to satisfy, assume a relation between them, viz, that the first differential co-efficient of θ, with respect to t, shall be the same whether A and B be variable or not These two assumptions are perfectly legitimate Now as,

$$\frac{d\theta}{dt} = -\text{A}c\sin(ct + \text{B}) + \frac{d\text{A}}{dt}\cos(ct + \text{B}) - \text{A}\sin(ct + \text{B})\frac{d\text{B}}{dt}$$

the latter assumption leads to the two equations

$$\frac{d\theta}{dt} = -\text{A}c\sin(ct + \text{B}), \quad \ldots(3)$$

$$\frac{dA}{dt}\cos(ct+B) - A\sin(ct+B)\frac{dB}{dt} = 0 \qquad .(4)$$

By differentiating the first, we have

$$\frac{d^2\theta}{dt^2} = -Ac^2\cos(ct+B) - \frac{dA}{dt}c\sin(ct+B) - Ac\cos(ct+B)\frac{dB}{dt}$$

Substituting, by means of equations (2) and (1), this becomes

$$\frac{dA}{dt}\sin(ct+B) + A\cos(ct+B)\frac{dB}{dt}$$

$$= \frac{ml}{ck^2} - \frac{nl}{ck^2}\left(\frac{d\theta}{dt}\right)^2 = \frac{ml}{ck^2} - \frac{A^2 cnl}{k^2}\sin^2(ct+B)$$

$$= \frac{c}{g}\left(m - A^2c^2n\sin^2(ct+B)\right) \qquad . \qquad . \qquad (5)$$

From (4) and (5) we obtain

$$\frac{dA}{dt} = \frac{c}{g}\left\{(m - A^2c^2n)\sin(ct+B) + A^2c^2n\cos^2(ct+B)\sin(ct+B)\right\}$$

$$\text{and, } A\frac{dB}{dt} = \frac{c}{g}\left\{m\cos(ct+B) - A^2c^2n\sin^2(ct+B)\cos(ct+B)\right\}$$

A and B may be considered constant in the small terms multiplied by m and n,

$$\therefore A = \text{const} - \frac{1}{g}\left\{(m - A^2c^2n)\cos(ct+B) + \tfrac{1}{3}A^2c^2n\cos^3(ct+B)\right\}$$

$$= a - \frac{m - A^2c^2n}{g}\cos(ct+B) - \frac{A^2c^2n}{3g}\cos^3(ct+B)$$

since $A = a$ when m and n are zero

$$B = \text{const} + \frac{1}{Ag}\left\{m\sin(ct+B) - \frac{A^2c^2n}{3}\sin^3(ct+B)\right\}$$

$$= \left\{\frac{m}{Ag}\sin(ct+B) - \frac{Ac^2n}{3g}\sin^3(ct+B)\right\}$$

Hence putting a and 0 for A and B in the small terms, we have

$$A = a - \frac{m - a^2c^2n}{g}\cos ct - \frac{a^2c^2n}{3g}\cos^3 ct$$

$$B = \frac{m}{ag}\sin ct - \frac{ac^2n}{3g}\sin^3 ct$$

$$\text{and } \theta = A\cos(ct+B) = A\cos B\cos ct - A\sin B\sin ct$$

$$= A\cos ct - AB\sin ct = A\cos ct - aB\sin ct$$

$$= a\cos ct - \frac{m}{g} + \frac{a^2c^2n}{g}\cos^2 ct - \frac{a^2c^2n}{3g}(\cos^4 ct - \sin^4 ct)$$

$$= a\cos ct - \frac{m}{g} + \frac{a^2c^2n}{3g}(3\cos^2 ct - \cos^2 ct + \sin^2 ct)$$

$$= a\cos ct - \frac{m}{g} + \frac{2a^2c^2n}{3g} - \frac{a^2c^2n}{3g}\sin^2 ct$$

The oscillation begins when $t = 0$ and $\theta = a$; hence the relation of m and n must be such that,

$$\frac{m}{g} = \frac{2\,a^2\,c^2\,n}{3g} \text{ or } m = \tfrac{2}{3}\,a^2\,c^2\,n$$

$$\theta = a \cos ct - \frac{m}{2\,g} \sin^2 ct$$

Let T be the time of an oscillation from rest to rest; then $\theta = -\,a$ when $c\mathrm{T} = \pi$,

$$\text{or } c = \frac{\pi}{\mathrm{T}}$$

$$\therefore\ \theta = a \cos\left(\frac{t}{\mathrm{T}}\,\pi\right) - \frac{m}{2\,g} \sin^2\left(\frac{t}{\mathrm{T}}\,\pi\right)$$

In this formula, m is unknown. To find it, observe the value of θ at the middle of the *time* of an oscillation; it will occur after passing the middle of the arc, suppose it equals $-\,\varepsilon$.

$$\therefore -\,\varepsilon = a \cos\frac{\pi}{2} - \frac{m}{2\,g} \sin^2\frac{\pi}{2} \text{ or } \varepsilon = \frac{m}{2\,g}$$

$$\therefore\ \theta = a \cos\left(\frac{t}{\mathrm{T}}\,\pi\right) - \varepsilon \sin^2\left(\frac{t}{\mathrm{T}}\,\pi\right)$$

From this formula (in which a, ε, and T are known), a table can be constructed giving corresponding values of t and θ, and by this, the *time* which corresponds to any *position* of the pendulum during an uncompleted oscillation may be readily found.

I am,

Yours faithfully,

MUSSOORIE,
April 23rd, 1868.

J. H. PRATT.

No. CXCII.

NOTES ON IRRIGATION IN THE BOMBAY PRESIDENCY

(2nd Paper.)

By H. Victor, *Sub-Engineer*, P. W. D.

Form of Bund.—The height being determined, the form depends on the nature and arrangement of the material employed in its construction.

Bunds are variously formed according to their locality, the principal object, however, is to combine economy with stability. The most usual construction is an earthen embankment; in some cases distinct lengths of masonry and earthwork, although the combination is not considered very effective; if the opening is narrow, masonry may be employed, or masonry walls retaining earth slopes; such might be found economical where the earth is not of a binding quality, the height of the work considerable, and where materials are cheap.

Earth will not stand without support at a greater angle with the horizon than that formed by its natural slope.

The natural slope of		rubble is	45°
"	"	loose dry shingle	39°
"	"	rammed earth	55°
"	"	common dry earth	35° to 47°
"	"	vegetable earth	26° to 30°
"	"	sandy loam	20° to 25°
"	"	sand and gravel	28°
"	"	dry sand	20° to 30°

so that a bund formed of common earth could not have slopes greater than about 35°, or $1\frac{1}{2}$ base to 1 perpendicular.

The interior and exterior slopes should be planes forming together an angle of not less than 90°, and the figure should be so formed that the lines of pressure passing from the interior face at right angles, may fall within its base, in order to increase its stability

The outer slopes might stand at a little less inclination than that formed naturally, while the inner, being subject to wash, must be considerably increased in length, thus sandy loam may stand at 20°, or about $2\frac{1}{2}$ to 1, but as soon as it became soaked it might slip to perhaps 12°, or $4\frac{1}{2}$ to 1. Sand banks subjected to a ripple have slipped down to 10°, or 6 to 1

Earth slopes may be retained considerably by stone pitching, this however is very liable to slip if the water gets behind it, as it cannot be pinned to any great depth, if it is used, it should stand on a firm bottom retaining course, closely packed and rammed behind with small pebbles mixed in clay, and the face joints carefully tuck pointed, turfing has been found effective, the cohesion acquired by laying turfs carefully in courses diminishing two-thirds of their thrust.

Upon the calculation that 1 cubic foot of rammed earth weighs 99lbs and 1 cubic foot of water $62\frac{1}{2}$ lbs, and supposing that earth would stand at any slope, we find that the base of a prism resisting the lateral thrust of a body of water does not require to be more than two-thirds the depth of the column it supports, so that all quantities above that are due to the natural slopes, the stability of the bund, and the prevention of percolation, consequently, when large works are projected, it should be a subject of close calculation which is the most economical, entirely earthwork, or the inner slopes retaining walls of masonry where the soil is not compact and a great base is required for the bund, the masonry might prove the cheapest

If the base of a triangular plane coincides with the upper surface of the water, then the centre of pressure is at the middle of the line drawn from the middle of the base to the vertex of the triangle, but if the vertex of the triangle be in the upper surface of the water while its base is horizontal, the centre of pressure is at three-fourths of the line drawn from the vertex to bisect the base.

The width of the top of a bund depends not so much on the pressure of water it has to sustain, which on the top surface level would be nothing, as the prevention of percolation The usual width is from 8 to 12 feet, thus allowing room for carts to pass along, either as a public track or for any repairs

The top of a bund must be made sufficiently high above the highest line of flood overflow at the escape weir, to prevent it being topped by waves, on a large spread of water, a strong breeze forms waves sometimes 3 feet high, that 3 feet falling on to a large slope might rise to 5 feet. The Bann Reservoirs in Ireland have embankments with stone faced inner slopes standing at 3 to 1 at a height of 5 feet above water level. The bursting of bunds usually arises from water running over the top of the earthwork and scoring away the back slope until the thickness is so reduced that it is unable to sustain the pressure of water behind it, additional security against such an accident is obtained by raising a low masonry parapet on the edge of the outer slope, paving the top and giving it a slight dip inwards to prevent the settlement of water.

To prevent leakage, it is usual to raise in the core of the earthwork a wall of impervious soil or clay, termed puddle, this may be about 3 feet thick at the top and have a slight batter down to its base, a channel being dug deeper than the other parts of the foundation to receive it, and thus cut off any porous strata through which the water might be forced under the bund, by the pressure from inside the tank. In preparing the design, the requisite depth may be ascertained by boring at short intervals along the centre and the outline of the base. Leaks are sometimes caused by rats and crabs working holes in the slopes, this may to a certain extent be prevented by facing them with clay and pebbles well rammed, as it dries it becomes both hard and water tight, besides forming a retaining slope. Newly raised embankment, after it gets saturated to any considerable depth, will leak a good deal, but as it settles the leakage stops, tipping fine sand down the inner slope has been found an effectual remedy. The surface soil should be excavated to a depth sufficient to receive the base of the work on a sound foundation if possible, and if the side slopes or the section to be filled in, are greater than the natural slopes of the earth of which the bund is formed, steps should be excavated, they bring the base horizontal, thus preventing lateral slip, by the pressure being vertical, and form a more perfect connection between the artificial and natural portions of the dam.

The design and working plans should be,

1. *The elevation.*—As submitted with the report, but finished, showing the section of the ground, the top of the bund, the level of the overflow, the levels at the outlets, and distinct dotted lines for the depth of excava-

tion, introducing at the same time any requisite masonry work, as weirs, sluices, &c.

2. *The plan* showing the top of the bund, the outline formed by the bottom of the side slopes on the ground, and the full extent of the base, with transverse lines for the masonry work, the portion above and below the ground line being contrasted by lighter or darker tints of the same color. A general view of the ground on each side, both longitudinally and transversely, should be included.

3. *Cross sections* showing all important details, contrasting in deeper or lighter tints of the same color, the core of the work if puddled, or the faces of the slopes if lined, if the ground has a transverse dip and the strata any peculiarity, it should be illustrated, showing also the character of the foundation and the depth to which puddle should be laid.

The whole to be drawn to such a scale that every important point may be introduced and plenty of room allowed to prevent a confusion of figured measurements. The drawings, however accurate, should have all the measurements entered as a check or immediate reference; 10 feet to 1 inch is a good working scale.

Masonry Bunds.—Masonry bunds have the advantage of requiring less expense for maintenance than those formed of earth, besides allowing a direct overfall for surplus water. The introduction of masonry, as previously stated, is a question of economy and resources.

The proportions of masonry bunds may be obtained by taking the weight of the fluid column supported, the specific gravity of the material, the cohesion of the mass to its bed, or the courses separately, which, if good chunam is used, is about $4\frac{1}{2}$lbs. to the square inch, and allowing for equilibrium one-fifth of the depth of water; this data worked out gives the thickness.

The ordinary rule for the thickness of masonry dams is (h representing the height of water, and x the thickness sought,)

At the top $x = h$ by 0.30

In the middle $x = h$ by 0.50

At the base $x = h$ by 0.70.

A bund of masonry may be considered as a wedge having a tendency to slide on its bed or lose its equilibrium; an illustration of the first case might arise from the perpendicular of this wedge being towards the water, thus having the whole surface exposed to a direct lateral pressure, the

second case might be when the wedge stands on its perpendicular or shortest side, the lines of pressure on its sloped face falling more beyond than within the base on which it stands. This in a great measure may be obviated by placing the wedge with the perpendicular on the outside with the body of water resting on the long slope, a waterfall, which might perhaps scour away the natural bed from beneath its lower side and endanger its stability, is the consequence, this defect is overcome by placing an apron beneath the fall or letting it down the dam by a succession of steps, thus breaking its force. The cheapest plan to effect this is to lay at the foot of the bund a number of large blocks of stone closely packed.

There are examples of masonry bunds formed like an arch laid horizontally with its convex side to the water, supported in its height by buttresses radiating from the back of the work to its centre, the springing points being let deep into the sides of the opening if they are abrupt, and the proportions for thickness greatly reduced. One now in existence has a height of 26 feet, a thickness from top to bottom of 4 feet, the buttresses at the back placed at clear intervals of 5 feet, each have a base 4 feet square and sloping up to nothing at the overflow height which is 4 feet below the top of the bund.

Wing walls are occasionally added where the soil on the slopes of the length section is loose, they are, on the water side, run deep into the ground to prevent leakage round the ends of the bund, on the lower side they are built with a greater splay to prevent erosion of the soil by the over-fall and answer the purpose of retaining walls.

The top of a bund serving as a waste weir may be so designed that, in the dry season, when the supply from the tank feeders runs low and about equals the consumption, additional storage capacity may be made by raising the head or overflow. This is done by constructing standards of masonry, or single stones will do, at about 3 feet intervals along the surplus water opening, and filling them up with branches of trees, earth, and sods, the construction being of that temporary nature that freshes may remove the obstacle.

The thickness of masonry bunds not being very great, iron discharge pipes similar to those used for water works might be economically introduced, from 5 to 10, 40 inches in diameter laid at the bottom and having valves to answer the purpose of sluices.

One great point to guard against in masonry work is unequal settlement,

where a portion of a bund may stand on doubtful ground, transverse channels should be cut about 3 feet in width at 3 feet intervals, and from 5 to 10 feet deep according to appearances, and filled in with concrete, a horizontal bed of the same composition being made over the whole area

Long masonry bunds when submitted to a constant stress of thrust tend to bulge, and in such instances counterforts are requisite

Combination Bunds —The principal fault in bunds the body of which is earth sustained between masonry walls, is their liability to burst by the earth absorbing moisture, and swelling Notwithstanding, examples of this style of construction are not unusual, in fixing the proportions this point should be well considered, as well as calculating that the retained earth might become a semi-fluid mass

The resultant of the thrust of a bank against a retaining wall is equal to one-third of the height taken on the inside face

The most advantageous form is when the retaining wall is leaning, to receive the thrust of the earth, but not so much however as to destroy its equilibrium if the earthwork settled Leaning retaining walls with counterforts at their backs, having the natural batter equal to the reversed batter of the inside of the wall, are both effective and economical

In some instances the back of the wall is vertical and the face at a slope of 1 base to 6 perpendicular, terminating at the top on a thickness of $1\frac{1}{2}$ or 2 feet

The most simple and practical rule for the thickness of retaining walls is for the base to be equal to half the height, the outer side to have a batter of 1 to 12 perpendicular, and the thickness reduced on the inside by stepping The tops should be in the same plane as the top of the earth behind them

Temporary Bunds —In hilly districts where large tanks cannot be formed with advantage, it is usual to construct across the small valleys temporary dams termed *Dukkas*, these assist both the irrigation of the land and to retain the soil (which otherwise would be washed away by floods) and in the course of a few years convert abrupt barren valleys into terraces of cultivation.

They are sometimes raised as high as 10 feet with an outside slope of 2 to 1 vertical, the body constructed of large boulders, and the inside a long earth or turf slope, at one end an opening is left large enough to carry off surplus water which runs down the next terrace, filling the lower dukka and so on the whole length of the valley, sufficient water is collected in each

to saturate the soil on which it stands and supply the crop on the lower terrace with two or three waterings in the event of a scarcity of rain; as the water is drawn from the beds, crops are sown in the silt

Dukkas cost from 10 to 100 Rupees, large ones, or those which hold a spread of water 10 to 20 acres, can be retained for 2 Rupees per annum.

On Weirs, Sluices, Discharges of Water, &c—In every tank project provision must be made for the discharge of surplus water On some works this is done by building masonry waste wells communicating with a drain running through the base of the embankment, the opening inside the reservoir being on a level with the fixed head of water and protected by a grating The plan is not a good one, although very often adopted in English works, its defects are the choking of the grating by rubbish, the insufficient escape for extraordinary floods, the action and the pressure of a high column of water acting on the joints of the masonry forming the passage through the bund, all these tending to injure, or destroy the work Waste wells are also difficult to repair

The most effective method to let off surplus water is by means of an overfall This must be constructed of masonry, the best position being near the ends of the bund, having wing walls both inside and out, and a channel cut to receive the discharge and keep it clear of the outer slope The features of the ground at the ends of the bund usually present a site for a waste weir If there is only a gentle rise above the top of the embankment, it could be cut down to that level, the soil assisting in the filling, and an opening formed, the bottom of which is on the intended overflow level, and the side walls allowing 2 feet between the top level and the maximum overflow head If it is required at any time to increase the capacity of the tank or raise the head of overflow, wooden traps or sliding shutters can be fixed, the discharge as before being led away from the embankment Should the ground be abrupt, a curved tunnel could be run round the flanks of the bund, the work being constructed of bricks worked in rings and laid in cement.

The security of a bund mainly depends on its waste weirs, the greatest number of accidents having arisen through the discharge opening being too small, it is therefore much more advisable to go to extremes on the other side, and afford a waterway that would meet every contingency, the discharge being easily regulated by self-acting traps

The volume of the greatest known fresh must be correctly ascertained, and in designing the escape it must be borne in mind that besides giving a discharge opening equal to the sectional area of the flood, it is necessary to allow also for obstruction in the passage by which the stream becomes contracted.

Overfalls are fitted with sliding shutters and traps in various ways; the most common method is a plank shutter sliding up and down in a groove and worked by a lever. The best plan is to have the shutters move upwards from a box: the water would then pass over the edge instead of forcing itself underneath. They can be raised or lowered by means of a windlass or capstan screw fitted to a cross head laid on the standards; the discharge can thus be more easily regulated and calculated.

The rules for finding the quantity of water passing over the waste board of a weir are:

1st. Multiply the depth of the stream running over the weir in feet, by the width of that stream in feet, and by two-thirds of the square root of its depth in feet and by the constant 5·1. The quantity obtained is the number of cubic feet discharged per second.

2nd. Multiply the square root of the cube of the head in inches by the constant co-efficient 5·1. This gives the discharge in cubic feet per minute for 1 foot in length of the overfall.

The co-efficient for friction, or the proportion between the theoretic and actual discharge, varies according to the depth, width and form of overfall. The numbers commonly used by English Engineers are 5·1, 5·15, 5·35 and 5·4 per foot per minute.

The head is the difference of level between the still water in the basin and the crest of the overflow.

Wings to a weir facilitate the discharge; to show the effect they have, a pair attached at an angle of 54° to an overfall 10 feet in length gave a mean co-efficient of ·459; without them it was ·371.

When waste boards or traps are fitted to an opening, their thickness should be increased according to their depth; thus if b equals the breadth and d the depth of the surface exposed to pressure from top to bottom, then the entire pressure is equal to the weight of a prism of water the contents of which is $\frac{1}{2}\ b\ d^2$.

The introduction of self-acting flood gates would be of importance where watchmen are not proverbially vigilant. Some work with a float attached

to a level Those however invented by Mr Bateman, the Hydraulic Engineer, appear to be the most simple and effective They are formed of 2 leaves turning horizontally on pivots which are placed below their centres so that the upper portions are of greater area than the lower, the upper leaf is larger than the lower and turns in the direction of the stream, while the lower leaf turns against the stream, it overlaps the bottom edge of the upper leaf and is forced against it by the pressure of water, the comparative area of the leaves and the position of the pivots is so arranged that, in ordinary states of the stream, the tendency of the current to turn over the top leaf is counterbalanced by the pressure of the water against the overlap of the bottom one, the counteracting pressures keeping the weir vertical and the leaves closed, the water flowing as usual through a notch in the upper leaf, but when the water rises above the usual level the pressure above from greater leverage overcomes the resistance below, and the top leaf turns over and pushes back the lower leaf The areas of the leaves above and below their axes have a ratio of 2 to 1, arrangements are also made for preventing them going over too far to recover themselves

Sluices —Sluices running through the body of a bund should be under perfect control, the opening protected by gratings, the valves or gates working either on a vertical pivot or in slides, and the passage being large enough to admit a man

The best form is either circular or egg shape, the inner faces and joints being cut and laid accurately in hydraulic cement, and the whole enclosed in a mass of coarse masonry with projecting bond stones, in order that a more intimate connection may be formed between the masonry and earth work

All masonry openings should be raised on a solid foundation and not in made earth, the earthwork rammed firmly against the masonry and for some distance round the orifice so that the water draft may not injure the embankment, there should be a protection facing and the bottom in front laid with an apron

In giving proportions to drains or sluices the following deductions from experiments will be found useful

1 The quantities of fluid discharged in equal times from different sized apertures, the head being constant, are to each other nearly as the area of the apertures

2 The quantities of water discharged in equal times by the same orifice,

under different heads of water, are nearly as the square roots of the corresponding heights of the water in the basin above the centre of the openings

3 That in general the quantities of water discharged in the same time, by different apertures under different heads, are to one another in the compound ratio of the areas of the apertures and the square roots of the altitude of the water

4 From friction, small orifices discharge proportionally less water under the same head than larger ones of a similar figure.

5 Where several orifices have equal areas under the same head that with the smallest perimeter will discharge the most, hence a circular form is the most advantageous

6 The quantities of water discharged in equal times, through horizontal tubes of equal diameters, under equal heads but of different lengths, are to one another in the inverse ratio of the square roots of the lengths, consequently, the longer the conduit, the greater the diminution of the discharge

7 The velocity of discharge is reduced by curves and bends

The orifice of an irrigating sluice should be made sufficiently large to give the full discharge required under the lowest head As previously stated, 6,000 cubic yards of water may be considered sufficient for *baghaet* or annual cultivation, the crops being such as sugar-cane, plantains, *pan*, successive vegetables crops, &c The supply might be distributed at the rate of four waterings per month, the three months succeeding the rains in 1 inch spreads, the three following months 2 inch spreads, allowing the remainder for starting the khureef crops or making up for deficiency of rain, and to carry on the hot weather cultivation, which is not very extensive, as the ground for a month or two is allowed to lay fallow

The allowance for rice cultivation in Madras is about 3 cubic yards of water per hour per acre while the crop is being raised

For corn crops, 1,000 cubic yards per acre would be sufficient, that would give three 1 inch spreads to assist the khureef, and four 1 inch spreads to bring the rubbee to perfection Cotton, pulse and oil seeds might also have this allowance

The distribution should be confined as much as possible to the ground immediately below the tank, as there is considerable waste in extending the distribution channels

Construction —Before commencing a work it is necessary to collect all the material and labor requisite to carry it out without delay when once

taken in hand If the project is a small one it should be completed before the rains, if one that will take two seasons in its construction, provision must be made either to divert the monsoon floods, or have some other means of discharging them, so that they may not injure the work, if the bund is of masonry, it makes little difference as the water may be allowed to run over the top of the work

Previous to excavating for the foundations, the work must be accurately lined out, first by laying down the centre line, driving in a peg at every 10 feet, at right angles to these other pegs must be driven showing the full width of the base according to plan, after the positions of these has been checked, the outline of the base is trenched, marking at the same time the extent of sluice foundations, &c, when these arrangements are complete, a temporary dam is raised if necessary on the inside trenching to keep the excavation free from water

The first portion of the work to be constructed after the excavation has been carried down to the requisite depth, and the middle channel filled with puddle and well rammed, is the masonry, after which the embanking can be proceeded with

The layers of earth should be not deeper than 2 feet without being rammed, at about every second layer a direct longitudinal level should be given, the cross section of the earthwork being curved from the slopes towards the middle, the puddle wall should be raised at the same time with the other work, in it the pegs for the 4 feet working levels can be driven and the widths for the profile of the slopes set off. It is unnecessary labor dressing the slopes until the work is up to its full height, it would be much more economical filling the embankment from the ends by wagons running on temporary rails up to the tip, but the work could not be consolidated so well. If the puddle wall in the centre is stiff enough to stand the weight, it might be raised 10 feet in advance of the rest of the work and the rails laid on it, the soil cart being constructed for side tipping To protect the slopes of earthwork, the planting of trees and sowing grass is recommended so as to bind the soil, if trees are planted they should never be near masonry as the roots are most destructive, as can be seen in any of the old buildings about the country, the banyan and peepul roots will work into the strongest masonry and choke small water-courses, creeping meadow grass and tamarisk are preferable.

None but hydraulic lime should be used in the masonry work, the lime

afforded by the locality should be tried, if it does not possess hydraulic properties as can be easily tested by trial in setting under water, the lime after being burnt must be mixed with a proportion of clay or black soil in powder, slaking the mixture and forming it into small lumps to be burnt over again In mixing up concrete, the usual proportions are one-third pulverised quick lime fresh from the kiln, one-third stone chips and one-third coarse sharp sand or pebbles, not more than what is immediately required should be mixed at one time Concrete should be thrown into a foundation from a height and beat with a pun until it begins to set After masonry courses are laid, it is a good plan to run the inside with hydraulic lime grouting. If bricks are used, to prevent their absorption of water a coating of boiled linseed oil can be laid on Where masonry is in that position that there is any chance of its sliding on its bed, the stones should be dove-tailed into a rocky bottom and each course joggled or cramped together, in brick ring turning, hoop iron, heated and dipped in oil, then laid between the horizontal and vertical courses, forms a good bond

Temporary dams for diverting a stream, protecting unfinished work or closing a breach can be constructed in several ways, gabions or fascines pinned together by stakes and weighted with masses of rock, the water side being puddled, are the quickest to construct, they do not however stand a rush of water The best plan, if the soil will admit, is to drive stout rafters about 6 feet into the ground like piles, in two rows 4 or 5 feet apart, the piles being driven at 1 foot intervals, these intervals are then closed by branches of trees or bamboos woven like basket work, the middle being filled up with rammed clay and stones

Instead of an apron being laid to receive the water of an overfall, an economical plan is to construct a well about 5 feet deep, the water always standing in it breaks the fall.

H V

CXCIII

THE CHAKRATA HILL ROAD

Report by MAJOR F W. PEILE, *Superintending Engineer, 1st Circle, N W Provinces, on the projected Cart Road from Kalsi (on the Jumna, in the Dehra Doon) to the new Hill Station of Chakrata*

THE plains' road is held to terminate, and the hill road to commence, at Kalsi. On the former the ruling gradient is 3 in 100, on the latter 5 in 100

Lower terminus —The large tope of trees near the Kalsi Tahseel affords an excellent terminus. There is a considerable extent of flat ground covered with large mango trees, water is brought on to the ground by a canal from the river Umlawa, drawing its supply from about a mile above the town It will be necessary to improve the channel of the water-course, and perhaps line it with masonry, in order to secure the water from being defiled in its passage past the town

Description of country, lower section —From Kalsi to Sahia, a distance measured on the line of $10\frac{1}{2}$ miles, the road lies on the high lands, which form the western side of the Umlawa valley These, in their lower features near the level of the river, abound in steep rocky ground and precipices, the river in many places passing through narrow gullies channeled out of the solid rock by the action of the water At an elevation of 800 or 1,000 feet above the river's bed, the ground is not so steep, and the surface is covered with soil and frequently under cultivation

Commissioner's line.—A line was laid out by the Commissioner rising rapidly from Kalsi, until these comparatively flat grounds were reached and then carried along them. It was asserted by the officers who laid out this line, that it rose on a regularly ascending gradient all the way to

Sahia, but when it came to be examined by the officers of this department, it was found that the ascending gradient terminated at Dudhow, and that for the remaining 4 miles or so of the line, there was a corresponding falling gradient to Sahia.

In addition to this disadvantage, this line encountered a very serious landslip, which presented an obstacle insurmountable by any ordinary means. This lies back in a valley around which the line wound. The soil of loose shale, slips from a height of about 500 feet above the line and over a length of about 1,000 feet. It was essential that this slip should be avoided altogether, which could only be done by crossing the gorge of the valley below it. Again at Dudhow the Commissioner's line was carried back and around a deep irregular recess, covering a length of 2 miles, whilst it progressed but 3 or 4 furlongs towards its destination.

The only work of any importance whatever executed on this line, was opening out a gallery in the precipices of the 3rd mile; all the remainder of the line was merely worked by a narrow pathway, along which a man could barely scramble. There was therefore no need for hesitation in abandoning nearly the whole of the Commissioner's line and adopting another, which should avoid the landslip, cut across the throat of the Dudhow valley, and present a gradually rising gradient and level portions, instead of a continuous rise followed by a fall. This new line it is true encounters several abrupt precipices and a good deal of rocky ground, but it saves several miles in length upon the upper line and encounters no difficulties whatever, such as are presented by the landslip already described.

The galleries in the precipices of the 3rd mile have been retained in the line, and doing this causes, in fact, the only difficulty with which we have to deal.

Zigzag above Kalsi.—Sufficient care was not taken in the first instance in determining a point from which the line should start at Kalsi, and it is not easy with our ruling gradient to reach the galleries. The line has to be carried back up the valley above Kalsi and to return, forming the only zigzag that occurs in the whole line. The turn has been made as easy as possible on a flat table with a radius of 80 feet.

It would be well I think, however, from several considerations to go a little further to the west at this place and secure certain advantages. As now laid out, with the exception of 300 feet at the turn, there is a steady pull up a gradient of 5 in 100, from Kalsi to the precipices, $2\frac{1}{2}$ miles, and the

turn is rather sharp, I am of opinion, that it would be preferable to carry the road on to the point marked A on the index map, where there is flat ground, which will permit of an easy turn being made on an increased radius, and the additional length of about 2,000 feet of line will permit of the gradient above being broken in several places by levels, which will relieve the draft very much

Gradients —Above the precipices, level portions have been inserted in every mile, alternating with gradients not steeper than 5 in 100 up to the 8th mile, from which point the line runs level to the crossing of the Umlawa It will be remembered that the Umlawa valley was said to be very malarious, and that it was considered essential to carry the line at a considerable height above the river The line, as at present laid down, lies generally about 600 feet above the bed from the 2nd mile to Dudhow, from which point they gradually approach each other till at Sahia they coincide In this upper part the valley expands very much and is free from jungle, and malaria need not be apprehended

Why line was not carried to east of Umlawa.—It may be asked why the line was commenced on the west side of the Umlawa and not on the east, on which side Chakrata, the final terminus lies The valley of the Umlawa on its eastern side is exceedingly precipitous, it consists, in fact of a single bold cliff rising abruptly to a height of about 1,000 feet from the river's bed, and extending for about 5 miles up its course, where it is broken by a ravine which discharges a water-course into the river It would have been impossible to cross this ravine, excepting at the level of its junction with the Umlawa, and at this elevation the whole road would have had to be cut out of the solid rock The valley behind the ravine to the east does not extend in the direction in which the line has to be carried, a long detour would have been necessary through Pokri, and the road would probably have been 35 miles long instead of 25

Large Bridges —There are but two works of any magnitude on the lower part of this section, that is up to Sahia, viz, the landslip bridge and the Umlawa bridge The former consists of a single span of 50 feet, a circular segment of 120° crossing the neck of what we have termed the landslip valley

In selecting the position for the bridge, it was necessary to keep entirely clear of and below the landslip, and at the same time not to go much below, as, the lower the line, the more rocky and precipitous the ground The rock

on either side is not of a nature to afford secure foundations of itself It is rather shaley and friable The bed of the stream is formed partly of this shale and partly of large rocks and boulders fallen from above The bridge proposed spans the throat of the valley, it is much larger than is required to pass the water, but it is necessary to throw back the abutments, in order that they may not be injured by the large masses of stone brought down It is also very questionable whether a reduction in the span, which would involve much increased work in wing-walls, &c, would be economical The drawings and specification for this bridge, supply all requisite information

Umlawa bridge —The Umlawa river rises in the Deobund range, about 10 miles above the point at which we cross it This point was selected by me with special regard to advantages of position for forming the bridge, bounded in a measure by the limits within which it was necessary to commence the ascent towards Chakiata The river collects the whole of the rainfall of the western side of the Chakiata, Pokree and Bariat spurs, of the eastern side of the Naga spur and of the southern slopes of Deobund lying between them There is a considerable perennial flow of water in the river, easily fordable in the dry seasons, increasing during rain to a perfectly impassable torrent In the course of about 18 hours after the cessation of heavy rain, it subsides and becomes fordable with some difficulty The fall in the bed between Sahia and Kalsi is 1,700 feet in a length of bed of nine miles about, from Dudhow downwards, it is steeper than from Sahia to Dudhow, indeed in the lower portion it falls in a succession of cascades The fall in the bed as measured for one mile above the crossing, is about 150 feet per mile

The water channel at Sahia is well defined, the valley has expanded and has a moderately level bottom, the river having channeled out a course for itself, and the ground rising from it on either side in cultivated terraces partly of artificial formation

When the river is in flood, the force of the water is very great, carrying large masses of stone before it I think it therefore expedient not to place a pier in the bed subject to rude shocks, but rather to span the channel by a single arch of 60 feet.

Good building stone abounds in the neighbourhood, and although for an arch of this size, it will be necessary to prepare voussoirs of dressed ashlar, the cost will not, I think, appear extravagant.

In this case the left abutment can be placed securely in a solid mass of rock which projects from the bank, and the position of which formed a chief feature in inducing the selection of this crossing The force of the current is directed towards this side The stream will pass as directly through the bridge as can be hoped for in the short reaches of a river of which the course is so tortuous.

Line above Salua —The character of the ground over which the line of road runs above Salua is very different from that below The slopes are generally easy, and comparatively but little rocky ground is met with The distance along the road from Salua to where the line cuts the ridge at the depôt, is 15 miles

Sainjh valley Bridge —As at first laid down, the line entered a valley bellow Sainjh in which it ran back for nearly a mile, the throat of this valley is formed by two abruptly projecting rocks, separated by an interval of between 60 and 70 feet and enclosing a chasm 70 feet in depth It was decided in the correspondence that has already passed, that this chasm should be spanned either by an iron girder or stone arch, and the long detour around the valley be saved Major Ross (Executive Engineer), found it impossible during the hot weather and rains to effect a sufficient examination of the faces of these vertical rocks, to decide whether from any part of them an arch could be safely sprung, and whether any support for a centering could be found at such a height above the bottom of the cleft During the early part of this cold weather, men will be employed in cutting steps or forming platforms from which the necessary examination may be made and measurements taken, and a definite proposal will then be made In the meantime the cost of the work has been estimated approximately at rupees 150 per foot run of bridge, and included in the general abstract

There is nothing else on this upper section, on which it appears necessary to offer special remarks

Marches for troops.—Troops proceeding to the sanatarium, will probably have to make two marches from Kalsi to Chakrata. The distance by the cart road is $25\frac{1}{2}$ miles from the lower encampment at Kalsi, to the point at which the line strikes the ridge near the depôt, the site for the regiment is about one mile further on Whilst the carriage must of necessity follow the cart road, the men might march partly by this road and partly by paths of steeper gradient that may be constructed to cut off some of the long detours.

The most favorable place for an intermediate encampment is Sahia, at the Umlawa bridge, here there is moderately flat ground and an ample supply of good water from the river. The lower section of $10\frac{1}{2}$ miles cannot be shortened by the expedient above-named, but the upper section of 15 miles may probably be reduced, by paths on a gradient of 10 in 100, to 13 miles. These paths may be opened at a very small expense, probably not more than 500 per mile, as the features and soil on the upper section are favorable.

Rest-house.—It is worth considering whether a rest-house might not with advantage be erected at Sahia for a company of men, in order that the troops might proceed by detachments and leave the more bulky part of their camp equipage in store at Kalsi. There is no ground on the line of road, on which a regiment could encamp in ordinary tents.

Water.—Water is found at intervals all along the line, but in abundance only at the landslip, Dudhow, the Umlawa, Korwa, and at the streams in 10 and 11 miles of upper section.

Surveys.—The surveys and estimate have been prepared with the utmost care. After the line had been flagged out, it was repeatedly examined and corrected where necessary, to secure the best points at which to cross the water-courses or to avoid difficult ground without falling into other errors or difficulties. A pathway was then cut on which the levels were taken, and a traversed line surveyed, a cross section was taken at every 100 feet, and these have been plotted on the plans in contour lines at vertical intervals of 50 feet. The nature of the soil was ascertained in each 100 feet, and has been exhibited by different shades of color on the drawing. Permanent bench marks have been set up at frequent intervals. The centre line of every culvert has been marked by strong pickets.

Estimates—excavations.—The quantities of excavation have been taken out mile by mile, for every 100 feet on a tabular form, classifying the work under the three headings of rock, stony and soil. The specifications of which are stated to be :—

Rock, that which can be removed only by blasting and the crowbar.

Stony, soil freely intermixed with stones of such nature that the combined use of crowbar and pickaxe is necessary for its removal.

Soil, that which can be removed by the phowrah.

Culverts.—The culverts have been arranged under the standard spans of

$2\frac{1}{2}$, 5, $7\frac{1}{2}$, 10 and 15 feet, any opening of larger size is classed as a bridge. The quantities of work in culverts are taken out mile by mile according to the standard drawings, allowance being made for extra work in those of which the piers are higher than provided in the standard

Width of road.—A 15 feet width of roadway clear, has been given to the culverts, one foot more than has been allowed in galleries cut in precipices The widths of road in the several portions have already been fixed by Government

Scuppers.—The small openings for discharge of road drainage 18 inches × 18 inches have been termed scuppers, they have been provided in the proportion of from 15 to 40 in the mile of road according to the nature of the ground The position of each scupper has been determined after a careful consideration of the features of the ground, the nature of the soil, gradient of road and extent of hill slope below which it occurs It may possibly be necessary to add to their number It is difficult to determine this until the road has been opened to its full width These scuppers are taken out by the mile in the estimate

Parapet walling.—The parapet walling is estimated mile by mile, divided into dry stone and in mortar. The dimensions and nature of the walling have been discussed in previous correspondence An opening of one foot is left at each culvert, and one of 3 feet at every 500 feet, to permit of cattle passing to graze on the hill side.

Metalling.—Metalling has been provided to the full width of the road and thickness of 6 inches

Compensation for land.—Compensation will have to be given for a very small amount of cultivated land in the bed of the Umlawa, and at the villages of Samjh and Koiwa. The whole of the rest of the line runs over waste ground.

Rates.—Total cost and cost per mile.—The rates have been determined by the experience already gained in opening out pathways and forming galleries in the precipices above Sahia The total cost per mile of the line, Rs 13,623, does not appear high by comparison with the cost of the Nynee Tal road I am informed that Rs. 12,000 per mile have been expended on that road by the local officers, although it is by no means complete, or constructed in so solid a manner as is provided in this estimate, *i e*, the culverts are all covered in with timber, there is no metalling, no part of the line is protected by a parapet wall, and, whereas we

have provided for forming the Chakrata road entirely in cutting, the Nynee Tal road is in a great part of its length formed by filling behind dry stone retaining walls, which have already failed in numerous places

On the other hand, I do not think that we have erred on the side of too great economy, the principal outlay is in excavation, the rates of which are based on the experience already gained

Method of calculating excavations —It is to be observed that in ground of this nature it is impossible to estimate the quantity of cutting with the accuracy attainable on ordinary roads, nor is it easy to foresee precisely where it may be necessary to substitute retaining walls for earthen slopes above the road The calculations have been based on the following considerations Where the natural slope of the hill side has a base of 2 to 1 perpendicular, the soil is generally not tenacious and frequently the dip of the strata will be with the slope, in this case we have assumed that the back slope may be left at 45° or base = perpendicular

Where the natural slope has a base of $1\frac{1}{2}$ to 1 perpendicular, the conditions point to the conclusion that the soil is tenacious, or that the strata lie nearly horizontally, and here we assume for the back slope a base of $\frac{1}{2}$ to 1 perpendicular It is in these places that we may most probably have to add retaining walls, as, where there is any symptom of failure in soil, it would be more economical to build a breast wall, than to add to the cutting by the very large area that would have to be taken out in section, to secure a back slope that would suit the soil In these cases, the sectional area of cutting saved by the breast wall, will probably nearly compensate for its cost

Where the natural slope is 45° or steeper, there is evidence from this fact, that the soil must be very tenacious, that it is of rock, or that the dip of the strata is opposed to the slope In these cases we have assumed sections varying, in the back slope, from $\frac{1}{2}$ to 1, to a vertical wall

Pattern cross sections of excavation —Nine pattern cross sections have been plotted on these principles, the areas of which are applied in the tables of quantities to each successive 100 feet, according to the local natural slope ascertained, as I have above said, by measurement on the ground

I do not see how we could arrive at an estimate of the quantities likely to be much nearer the truth, until by opening perhaps half the width, we can ascertain the exact nature of the soil at every point It may perhaps be accepted as sufficient to promise that on the work reaching this stage

the table of quantities shall be revised with a view to determining whether the gross quantities provided will cover the cost of the completed work

The quantities and cost of all the other descriptions of work, can of course be arrived at very closely, an exception within a moderate limit being allowed in the case of the scuppers, to the number of which some addition may in certain places be necessary

Abstracts of estimate—Two abstracts have been prepared showing the quantity of each description of work in each mile in the upper and lower sections separately, and a general abstract in which the gross quantities are collected

Separate estimates, landslip and Umlawa—Separate estimates in detail have been prepared for the landslip and Umlawa bridges, the cost of them being included in the general abstract The cost of a bridge to cross the throat of the Sairjh valley has also been included at Rs 150 per foot run of bridge

Inspection houses—Provision has also been made for an inspection house and overseer's residence to be built at Sahra, for which an estimate will be submitted

I may observe that as the whole of the estimates have been drawn up, and the drawings completed by the Executive Engineer in direct consultation with me, he has confined himself to preparing specifications for the work, and has not drawn up a report which would have been but a repetition of what I have here stated

In conclusion, I would beg to express the hope, that the Government will be satisfied with the manner in which this project is submitted

A great deal of the out-door work has been executed by Major Ross and his Assistant Engineers, Mr Blair and Lieutenant W. G Ross, R E, during the hot weather and rains, at the cost of serious exposure on very difficult ground, where frequently a footing could barely be maintained and where a malarious atmosphere abounds The drawings have been carefully and neatly drawn by Mr. Blair for the lower, and Lieutenant Ross for the upper, section, and the three officers have combined in the labors of taking out the details of work

I have to record my obligations to Major Ross, for the patiently persistent manner in which he has insisted on the work being carried to a close, in the face of many difficulties that at first appeared insurmountable, and under circumstances which gave good reason for apprehending

that the officers must succumb to the evil effects of the climate and locality

Corporal Egan and Sapper Sinclair of the Royal Engineers, Overseers of the department, assisted efficiently in the work, and are both highly commended by Major Ross

---

Estimate framed by the Executive Engineer of the probable cost which will be incurred in constructing the hill cart road from Kalsi to Chakrata

SPECIFICATION.

Excavation.—This item has been divided into 3 heads, viz.—

1. *Earth*, that which can be easily removed by the phowrah.
2. *Stoney soil*, requiring the use of pick and phowrah.
3. *Rock*, that which necessitates blasting and removing with crowbars.

The whole of the roadway to be in cutting, except where it passes through fields, where, up to a limit of 5 feet high embankment, the roadway will be in cutting and embankment

The general width of the roadway to be 18 feet exclusive of parapet walling when the latter is necessary, which will be the case when the slope of the hill is over 30 degrees, the excavation will be 20 feet, which allows two feet for width of parapet walling

Where a large precipice occurs, a gallery, (which will reduce the roadway to 12 feet), of not over 500 feet in length will be cut The total width of cutting here, however, will be 14 feet which allows 2 feet for width of parapet walling, where the slope of the hill does not exceed 30 degrees, *i e*, two to one, the back slope of cutting shall be 45 degrees, *i. e*, one to one, where the slope of the hill does not exceed 45 degrees, the back slope of cutting to be half to one, all rock to be cut vertical. The formation level of roadway shall be cut with a slope of 3 inches towards the inside, and along the inner edge, the excavation shall be slightly deeper in order to form a side drain, but which shall have no decided section as shown in drawing

Culverts.—The foundations and flooring to be of uncoursed rubble masonry. Superstructure and arching to be of coursed rubble.

Uncoursed Rubble Masonry.—A portion of one-fifth of the whole face of the wall to be headers.

Every stone to be laid carefully on its bed, and all rounded stones to be rejected

The interstices to be carefully filled with chips and the work to be well grouted with mortar

Coursed Rubble Masonry —In culverts up to 15 feet span, no course to be less than three inches in thickness

No stone to be less than nine inches long upon the face, or less than eight inches on the bed

Coursed Rubble Arching —No stone to be less than the thickness of the arch, or less than one foot in breadth.

In arches up to 15 feet span, no course to be less than three inches in thickness.

The arches to be built in alternate courses of headers and stretchers.

The headers in all cases must extend right through from the intrados to the extrados of the arch, and be not less than twelve inches wide

The stones in the face rings to extend right through from intrados to extrados

The stones to be dressed and summered true and out of winding, so that no joint shall, with its mortar, exceed three-eighths of an inch in thickness, and the joints throughout must average less than three-eighths of an inch

All joints on the face work and intrados to be rubbed and properly pointed, and the whole work made clean and neat

The drawings of the culverts given show the general design thereof

The mortar in the above works to consist of stone, lime and budgeree, the proportions of which will be determined hereafter by experiment

In the estimate equal parts are entered and estimated accordingly

Scuppers —Parts of the flooring, abutments and the covering to be constructed of hammer dressed stones, and the remainder of the work of dry rubble masonry, as shown in plan.

The mortar to be the same as for the culverts

Parapet walling —To be constructed of dry rubble masonry, except at galleries, where the masonry will be set in mortar The parapet walling to have a foundation of one foot deep and $2\frac{1}{2}$ feet wide, and to be $3\frac{1}{2}$ feet high and 2 feet wide

Retaining walls —To be constructed of uncoursed rubble masonry, with a batter of one in twelve, care being taken that the face be lined with large stones, and provided with sufficient number of deep holes.

Metalling.—To be of broken stone.

The whole width of roadway to be metalled, and the metal to be 6 inches in thickness.

The stones to be broken to a size to pass through a $1\frac{1}{2}$ inch ring.

The metal to be saturated with water and rammed with rammers until thoroughly consolidated.

The provincial standard specifications to be adhered to as much as possible in all these works.

GENERAL ABSTRACT

c ft		Rs	Rs
	EXCAVATION		
95,99,582	Earth, @ Rs 2-8 per 100 feet,	35,323	
1,51,25,151	Stoney soil, @ Rs 4 per 1,000, ..	60,500	
86,76,406	Rock, @ Rs 10 per 1,000, ...	86,764	1,82,587
	CULVERTS		
78,929	Uncoursed rubble masonry, 42-23, @ Rs 12 per 100,	9,471	
1,36,330	Coursed rubble masonry, 41-19, @ Rs 14 per 100,	19,086	
12,417	„ arching, 41-20, @ Rs 16 per 100,	1,987	30,544
	SCUPPERS		
85,840	Hammer dressed stone in morter, @ Rs 20 per 100,	17,168	
42,624	Dry rubble masonry, @ Rs 4 per 100, .	1,705	18,873
	PARAPET WALLING		
10,62,520	Dry stone walling, @ Rs 2-8 per 100, ...	26,563	
62,700	Stone walling set in mortar, @ Rs 10 per 100, .	6,270	32,833
	RETAINING WALLS.		
19,350	Uncoursed rubble masonry, 42-23, @ Rs 10 per 100,		19,350
	METALLING		
12,52,110	Broken stone metal, @ Rs 3 per 100,		37,563
	Compensation for land,		2,000
	LANDSLIP BRIDGE.		
6,182	Uncoursed rubble masonry, 42-23, @ Rs 12 per 100,	742	
18,944	Coursed rubble masonry, 41-19, @ Rs 14 per 100, .	3,789	
2,560	Ashlar arching, @ Rs 100 per 100, .	2,560	7,091
	Carried forward, Rs .		3,30,841

UMLAWA BRIDGE

Brought forward, Rs	.	3,30,841
88,250 Uncoursed rubble masonry, 42-23, @ Rs 12 per 100,	1,059	
1,92,970 Coursed rubble masonry, 41-19, @ Rs 20 per 100,	3,859	
34,120 Ashlar arching, 41-20, @ Rs 100 per 100,	3,412	8,330
r ft		
60 Sainjh valley bridge, @ Rs 150 per foot, ...		9,000
1 1st class inspection bungalow at Sainjh, ...	2,000	
1 2nd class inspection bungalow at Korwa, ..	1,000	3,000
Total Rs, ..		3,51,171
Add 5 per cent for contingencies,		17,558
Grand Total Rs, .		3,68,729

Note—The whole project will be completed within 2½ years from date of receipt of sanction

No CXCIV.

COLORED BRICKS AND TILES

Notes on the manufacture of Colored Bricks and Flooring Tiles in England By PETER KEAY, *Head Master, 2nd Department, Thomason College*

SOME months ago, when leaving India for England, I was requested by Major Medley, R E, Principal of the Thomason College, to try and gather some information on the subjects referred to at the head of this paper

Again, in writing to me on the same subject lately, he says—

"Good sized specimens of the raw clays used would be most valuable to our Museum, for comparison with Indian clays, and each specimen should be accompanied by one of the finished bricks or tiles made from it

"Encaustic tiles of variegated patterns and colors, require, I know, costly machinery and skilled superintendence, but my idea is, that colored bricks and flooring tiles, unglazed, of one color, without a pattern, could be made up here very well What coloring matters do they use, other than what are inherent in the clay?

"Make yourself acquainted with every detail of the manufacture and let me have a paper on the subject, showing what changes in the details would be necessary for India How does the nature of the fuel affect the coloring of the burnt tiles or bricks?

"We want white bricks—cherry red bricks—blue bricks—and gray bricks, if possible, out here, so as to enable us to give solid ornament *without* plaster"

The following notes of information have been collected to meet, to some extent, the above requirements, and specimens of the clays, the finished articles, and coloring matters used, have been forwarded. They are marked and numbered so as to correspond with the explanations following *

* These have been received and deposited in the College Museum, where they can be inspected —[J G M]

The subjects may be arranged under the following headings, namely :—

1.—Terra Cotta

2.—Coloring of bricks, &c , by mixing certain coloring matters with the clay

3.—Coloring bricks, &c , by dipping them in a coloring liquid after they are burnt

4.—Flooring tiles

Terra Cotta.—This is the term applied to a material very extensively used in England for ornamental work of various kinds, such as cornice mouldings, vases, statuary, and for many similar purposes, as a substitute for carved stone work

It consists of a superior description of earthenware, prepared and burned in much the same way as bricks or tiles, but with greater care and nicety both as regards the selection and preparation of the clays used, and also in the mode of burning

The principal feature in the material however is, that it always contains a certain proportion of ground glass or pottery ware, or of both This material has the effect of reducing the shrinkage of the brick, &c , in burning, and also of making it unusually hard and impervious to water, so that it stands the effects of any weather better than most kinds of stone

[The article marked A is a fair specimen of terra cotta . It is made from Poole, or Dorsetshire clay, and contains about the quantities of ground glass and crockery-ware detailed in No 1 (*see* below)

Specimen of the raw material is in small box marked A_1.]

The clay for this kind of material is prepared with great care, and so it is also for all kinds of ornamental bricks and tiles.

It is sifted in a dry state, and then mixed in large tubs with a great quantity of water, being worked about with spades or similar tools, the ground glass or pottery ware being mixed with it as thoroughly as possible It is then lifted out and placed in large rough wooden boxes, with joints sufficiently open to allow the water to run off When this has drained off, and the clay become dry enough for the pug-mill, it is passed through it, *several times*, and is then fit for the moulders' table

The following are the details of mixture for different classes of terra cotta in use here :—

No 1 For best class of large goods

10 Bushels of Devonshire clay, specimen No *
5 Bushels of crushed pottery ware, *white*
2 " ground glass, *common bottles*
2 " white sand,
1 " calcined flint, } may be omitted if not available

Shrinkage about $\frac{1}{4}$-inch to the foot

Time of burning, from 5 to 6 days †

No 2 —For architectural purposes

10 Bushels of Dorsetshire, or Poole clay, specimen No 3
4 " crushed pottery
1 " crushed glass, *common bottles*
1 " white sand,
$1\frac{1}{2}$ " calcined flint, } may be omitted

Shrinkage, $\frac{3}{4}$-inch to the foot

Time of burning, from 4 to 5 days

No 3 —For architectural purposes.

8 Bushels of red clay from Everton in Surrey, or London clay, specimen No 2
3 Bushels of crushed pottery
2 " white sand
1 " ground glass

According to color required, add a portion of red ochre and burnt umber.‡

Shrinkage $\frac{7}{8}$-inch to the foot

Time of burning, about 4 days

No, 4 —For red flooring tiles and bricks

12 Bushels of red clay, specimen No 2
5 " sand
2 " crushed pottery, or *vitrified brick*

Shrinkage, 1 inch to the foot

Time of burning, about 4 days

* There is no specimen, but it is very like Poole, or Dorsetshire clay, marked No 3

† The time required for burning these specimens, as noted for each, is the time necessary after the kiln has been fairly heated, and all moisture driven off from the goods This will require a gentle firing of four or five days, and when all sign of steam from the kiln ceases, the firing is continued vigorously then for about four or five days longer, till the goods are sufficiently burned

See further remarks under the head of *Burning*

‡ Red ochre burns yellow, and yellow ochre burns red

No 5 For roofing tiles

9 Bushels of red clay
5 „ sand

Shrinkage and time of burning, the same as for No 4

The pottery ware used as above is not crushed to a very fine powder, but is reduced rather to a gritty state, as may be noticed by the particles of it visable in the specimen

The glass, on the other hand, is reduced to a fine powder

Coloring of Bricks or Tiles —There are two methods in use for this purpose, one by mixing certain coloring matters with the clay before burning, and another by dipping the brick in a coloring liquid after it is burnt

The first method may be adopted when the coloring matter is available in sufficient quantity, and is not too expensive, but the second method is particularly well adapted for expensive colors, and admits of a great variety of colors being produced at comparatively little cost, and with little risk of failure or trouble

The following three cases come under the head of the first method

1 —*To make brown or stone colored clay into a light red when burned*

Take 6 bushels of clay
„ 1 „ yellow ochre
„ 1 „ red brick, or *soorkee*

Mix together and put through pug-mill, as described above

---

2 —*To give a yellow color to bricks.*

For bricks of this color, the clay should be of the kinds marked Nos 1, 3 and 4, in the specimens, *i e.*, Bedfordshire, Dorsetshire or Suffolk clay, but the yellow color will be increased, or produced from red clay even, by adding *red ochre*, and crushed yellow brick and pottery ware, if available.

---

3 —*For best blue bricks or tiles*

1 Bushel of ground flint
1 „ best fine clay, *sifted*
½ „ ground glass, *common bottles*
3½ „ French ultramarine

Mix well together and put through pug-mill, as before

Note—This mixture and the next are rather intended for plain flooring tiles, or for filling in the colored portions of a pattern in an ornamental tile, than for bricks

Bricks for these colors can be obtained more suitably by dipping in a coloring liquid, as explained further on

Some coloring matters change their colors when exposed to great heat for instance, red ochre burns yellow, and yellow ochre burns red

The following retain their colors though exposed to white heat—French ultramarine, light red, and Indian red—*see* specimens

---

4 *For black bricks or tiles*

1 Bushel of any clay, *not red*
1½ " ground cinders, *not very fine*
2 " manganese—*see sample*

If for best work, such as terra cotta, add

1 Bushel of ground black glass

Mix and put through pug-mill, as before

The second method of *Coloring, by Dipping*, is a very simple process, and bricks or tiles colored in this way will stand any amount of exposure to the weather without losing their color. There is another good result from coloring in this way, the surface of such a brick will never take on any vegetable matter when exposed to a damp atmosphere

The materials used for the coloring liquid are—Turpentine—linseed oil—and litharge, with coloring matter as may be required

Where I saw it used, it was done in this way —There was an earthenware box, a few inches larger each way than a common brick, and it was about half full of a red liquid of about the consistency of good rich cream

The bricks, &c., to be colored were laid upon a flat surface—iron plate—with a fire underneath The place might be large enough to contain a couple or three score of bricks The bricks got heated, not to a great heat, but too great to admit of their being handled.

They were then taken, one at a time, and dipped into the liquid in the box for a few seconds, then placed on a table to dry, which they did in a few minutes. They were then taken and slightly washed with the hand or a bit of rag, in a trough of cold water, and placed aside to dry This completed the whole process

If the brick be open and porous such as any common brick is, the coloring matter will penetrate about one-eighth of an inch, but for bricks containing a portion of glass and crockery, such as terra cotta, the coloring matter will not penetrate so far However, in either case the color given to the brick is thoroughly *pucka* and lasting (*see* specimens where the bricks have been *partly* dipped so as to show the new color, and the original color of the brick)

The following are the proportions used for some of the colors —

1. *For dark red bricks*

$1\frac{1}{2}$ pint of turpentine
$1\frac{1}{2}$ „ linseed oil
$\frac{1}{4}$ pound of litharge, *see specimen*
$\frac{1}{2}$ ounce of India red, „

Mix well together and use as explained above

2 *For blue bricks*

1 pint of turpentine
1 „ linseed oil
$\frac{1}{2}$ ounce of litharge,
1 pound of French ultramarine, } *See specimens*

Mix and use as above

3. *For black bricks* (*see* specimen marked B)

2 ounces of litharge
6 „ manganese
4 „ linseed oil, boiled
6 „ turpentine

4. *For grey bricks* (*see* specimen marked C)

3 ounces of white lead
1 „ litharge
1 „ manganese
2 „ boiled linseed oil
4 „ turpentine

From these specimens it will be seen that any color may be produced, the fundamental items being the *litharge*, *turpentine* and *oil*

Coloring materials could be had in great variety in India, in any bazar almost

If a brick be dipped in one of the above liquids, and again exposed to a great heat it will become glazed I saw this done with some specimens, but the glazing was not very perfect, as the kiln had not got very well heated just where the specimens were placed

These coloring liquids are sometimes used where the brick cannot either be dipped or heated conveniently, as in the case of bricks already built into a wall. In such a case the bricks are carefully cleaned and the liquid heated and laid on with a brush It does not penetrate the brick so well this way, but the color stands the effects of the weather remarkably well, even in this atmosphere.

Burning —The burning of terra cotta goods of all kinds, including ornamental bricks, has to be managed with great care and nicety, but there is one peculiarity in the operation without which the uniformity of color necessary for such goods could not be attained The goods are completely enclosed in a case of fire brick, or *muffle* as it is called—and the fire is not allowed to come in contact with them in any way

The accompanying plan of the kiln will show the nature of the arrangement

The inner face of the main walls and the muffle are of fire brick, and the muffle, as will be observed, forms a complete shell inside of the kiln The muffle has a thin arched floor, under which the fires play, and between the walls of the muffle and the walls of the kiln, there are small open spaces left so as to allow the heat from the furnaces to circulate completely round, and above the muffle. It has an arched top also, and corresponds with the general form of the kiln. The space between the muffle and the walls of the kiln is about four inches, but at the top it is about a foot

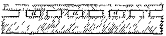
The goods are arranged, rather openly, inside of the muffle, and in the case of articles that would be likely to get injured from having others placed upon them, it is usual to make slight and temporary pillars of fire brick, as may be required, in the body of the kiln, and, on these, broad slabs of the same material are placed for the support of the various articles to be burned

The whole weight of the goods rests upon the arched floor of the muffle, and as this floor must be thin enough to allow the heat from the furnaces underneath to pass through it readily, and strong enough to support the weight of the goods, the difficulty is met by constructing a series of ribs

in the arch, of greater depth than the floor generally These ribs are at intervals of about 6 inches

To allow the heat to penetrate as easily as possible, the walls and top of the muffle are constructed of brick-on-edge

The plan of a portion of the main wall of the kiln and the muffle wall is like the rough sketch in the margin, and the heat from the furnaces comes up through the spaces marked *a* The arched roof of the muffle abuts upon the main wall



The main walls of the kiln are clamped and held together by strong iron bands. There is one that goes all round it, up near the top, where the arches of the kiln and muffle spring from, and there are upright cast-iron ribs at each corner, connected with iron rods running along the masonry of the main walls

The expansion and contraction of these iron bands cause the walls to crack a good deal, but the iron holds them together, and they would not stand without this support

The kiln is filled and emptied at the door shown at the back

When filled, this door—first the muffle and then the main wall—is built up, but there is an earthenware pipe built into the masonry nearly perpendicular to the face of the wall, and through this pipe, the steam from the damp goods escapes during the first three or four days of the firing. It serves also as an opening for observing the state of the goods during the burning, and it is usual to place a few pieces of material to be burned, made into the form of rings near the inner end of the pipe. One of these rings, or *proofs* as they are called, can be drawn out at any time with an iron rod, so as to observe the progress of the burning *

A common black bottle is generally placed also near the *proofs*, and when it melts and sinks down into a shapeless mass, the burning may be considered about done.

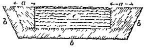
When finished, the whole of the furnaces and other openings are carefully closed up and roughly plastered with clay, and the kiln left to cool for a week or so, after which the door may be opened, and the goods taken out when cool enough to be handled.

If goods of different colors, such as white clay and red clay, be placed

* Any kind of fuel that will burn briskly will answer for the kiln Both coal and coke are used here, but wood would do quite well

close together in the kiln, they will mutually tinge each other, that is, the red goods will receive a tinge of white, and the white ones of red

Moulding.—All terra cotta work and ornamental bricks are moulded in plaster of Paris moulds The peculiarity of these moulds will be understood from the rough sketch in the margin, which represents a section through the mould



The outer shell of the mould is represented by the part marked *b*, and there are four separate pieces marked *a*, two side, and two end, pieces, *c* represents the clay of the brick

The clay is very carefully pressed into the mould with the hand, first round the edges, and then in the centre, and the clay is used in a stiffer state than for ordinary brick moulding When the mould has been properly filled and finished off at the top, it is usual to scoop out a couple or three holes in the brick with a scoop-shaped hand tool The object of this is to facilitate the drying and burning of the brick. These holes also are useful in unloading the kiln should the bricks be too hot to handle, as they may then be pulled out with a hooked iron rod, and they give a hold to the mortar in the masonry.

To take the brick out of the mould a small board is placed on the top of it, and the whole inverted. The part *b*, is then lifted off, and the side and end pieces removed By this arrangement, there is no risk of spoiling the shape of the brick, as there would be in the ordinary method of brick moulding

A specimen of such a mould is forwarded

The whole of this moulding work is done with great care, and there is no question raised as to how many bricks, &c, can be made in a given time, but rather of how *well* they can be made Indeed, one never hears, in the great private firms here, so far as I can learn, the never ending worry about rates, so familiar to every body in India Whether work may be carried on with more economy here than in India, the quantity and means being equal, is more than I can tell, but that people who have to do work here are less cramped and worried about cost and accounts, there can be no doubt. Indeed, the majority of the people who superintend work here could not really do the paper part of the work required in India, although thoroughly well up in the engineering part of their work.

Flooring Tiles.—Little need be said about flooring tiles, unglazed, of one color, beyond what has already been explained under the head of coloring and terra cotta. Tiles of this kind can be made and burned in the same way as colored ornamental bricks or other similar articles.

To attempt the best kinds of ornamental glazed tiles would be out of place in the present state of such knowledge in India, and I have had no opportunity of learning anything worth while on the subject. There seems no reason, however, why a fair description of tile, with pattern, but unglazed, might not be produced.

The way they are made here seems simple enough.

A tile is made of, say, good red clay, with a portion of glass and crockery, and a pattern stamped into it to a depth of about a quarter of an inch.

Then lay on the stamped surface a coat of the following mixture with a brush—

1	of clay	mixed with water.
2	of ground flint or glass,	
$\frac{1}{3}$	of dry white lead,	

This will prevent the different colors from running into each other.

Now, the several parts of the pattern may be filled in with clays prepared and colored as may be required, and when properly finished in this way, the tile is dried and burned.

Two specimens of tiles with the patterns stamped, but not filled in, are forwarded. These specimens have been burned to preserve them from breaking, but in making such a tile, the colored clay would be filled in the pattern before burning.

The stamp for such a pattern would be made from plaster of Paris.

Under the head of flooring tiles, I may mention an excellent kind of flooring brick in use here for stores and such places, and which appears to be remarkably well suited for barracks floors, and similar purposes, in India.

It is made from ground clinkers, vitrified bricks, and such materials, mixed with a portion of good cement.

The clinkers, &c., are ground to a rough state only, and when well mixed with the cement, the material is moulded and left to set, not burned.*

A specimen is forwarded.

* Bricks of this kind are very hard and heavy, and wear remarkably well under heavy traffic.

Grinding Mill.—This is an important article in all work of the kind referred to in the foregoing pages. The accompanying drawing represents one of the best description of this kind of machine.

The two cylinders are of cast-iron, and weigh from $1\frac{1}{2}$ to 2 tons each. Their faces are covered in with cast-iron plates flush with the flange, to prevent the latter from lifting up the material being ground.

The cylinders work in a large cast-iron pan, which contains the glass, crockery ware, or other material to be ground.

The thin curved pieces attached to the chains, drag through the material and prevent it from getting caked under the cylinders.

The grating looking piece in the bottom of the pan is for the purpose of emptying it, by letting the material pass down when ready. The piece slides inwards a little, by means of a lever handle, till the slits in the piece correspond with similar ones in the bottom of the pan.

It takes about two horse-power to work one of these mills.

The drawing seems to require no further explanation.

Postscript.—*Blue Bricks*.—Being down in Birmingham a few weeks ago, I observed that several of the railway works were built of a very fine kind of blue bricks, and on enquiring, found they came from Staffordshire. I went down to one of the principal brick-works there to make enquiries, and found the people quite willing to give me all information I required.

The color of the bricks appears to be due to the iron that is in the clay naturally, but the bricks assume the blue color only if subjected to a very great heat in the kiln. If burned to a certain pitch they become red, like ordinary bricks, but if the fire be increased and continued for about twenty-four hours longer, the color changes into a very dark blue, or nearly approaching a black.

It is usual also to throw from two to three shovels full of common salt into each furnace just before the fires are allowed to die out. This has the effect of producing a glazed surface upon the bricks.

They are the hardest and most durable *looking* bricks I have seen, and they seem to stand particularly well in all the works of the Great Western Railway, where I saw them.

They are much used for pavement too in the side walks of the streets, and stand the heavy wear well.

In moulding them, the dry moulding system is used, but instead of sand

for sprinkling the mould, they use a material known among the people as "swarf." This is merely the dust which collects from the grinding of edge-tools, and such like, and which can be had in considerable quantities in those localities. This dust helps to intensify the color of the brick, and in fact produces a kind of surface of iron matter upon the brick. But independent of it, there is sufficient iron in the clay to produce the color, *provided the brick be burned sufficiently*. I was told that other clays will not stand the great heat necessary for these bricks.

I brought with me a specimen brick, sample of the clay, and sample of "swarf." These will be sent to the College.

P. K.

No CXCV

ARCHING OF THE DINGUREE BRIDGE

Note on method adopted for raising the arches of the Dinguree Bridge on the Cawnpore Terminal Branch, Ganges Canal By Major H. A Brownlow, R E, *Superintending Engineer*

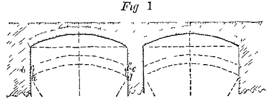
The object of raising the arches was to obtain a clear head way of 20 feet by 10 feet for boats It was, of course, all important not to interfere with the existing navigation by obstructing the waterway of the bridge with centerings and scaffolding, and it was also most desirable, on the score of economy and future convenience, not to excavate a temporary channel for the canal round the work

The bridge consists of two arches, each 30 feet span, with 18 feet clear width of roadway, and the arches had to be raised $8\frac{1}{2}$ feet As there was but a limited amount of village traffic over the road, carts were turned along the canal bank to the nearest bridge, a distance of about 2 miles, foot passengers being allowed to pass over direct, so long as they did not interfere with the work in progress The superstructure and backing were then stripped off, leaving the arches bare, the piers and abutments were carried up to the new level of springing line, and the centerings for the new arches were constructed on the old ones As soon as the new arches were ready, the centerings were removed, and the masonry of bridge completed up to level of roadway Temporary parapets were then erected, and the traffic was turned over the bridge again

The old arches were taken down by carefully cutting away ribs of one foot in width, from each face, in a direction perpendicular to the abutments

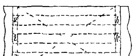
and pier, commencing from the key brick and working down to springing line on each side. The cohesion of the mortar in the arch amply sufficed for the support of each rib without throwing any strain on the triangular portions *abc*, *def*, in *Fig.* 1. When each arch had been removed, with exception of a rib about one foot wide in the middle, centerings supported on boats moored underneath were keyed well up to the remaining portions, which were then removed without any shock to the work.*

Fig. 1



The greatest care was observed in cutting the arches away equally on each side of the pier, so as to avoid any unequal thrust on it, and at first they were only removed to within 6 inches of the pier and abutment faces, leaving the projecting portions to be cut away at leisure by careful and experienced masons. It was objected to the above plan that the small triangular portions of arch work *abc*, *def*, (see *Fig.* 1,) would be included in the pier and greatly weaken it. It was, therefore, proposed to pick them out subsequently, a foot at a time, squaring the hole, and refilling it with first rate masonry in the same manner as if the pier were being underpinned. It was also proposed, as an alternative,† to divide the width of arch into a convenient uneven number of equal parts, to cut out every alternate triangular portion of skew back *gh*, *ik*, &c., in *Fig.* 2, and to build up the pier and abutments in horizontal layers over these spaces, leaving the ribs *gh*, *ik*, &c., supported by cohesion of the adjoining and parallel ribs. It was ultimately decided to leave the triangular portions untouched, as the masonry was excellent and thoroughly indurated; *abc* in *Fig.* 3, represents portion of skew back included in pier, $ab =$ thickness of arch $= 2$ feet, $bd = ab \sin 30° = 1$ foot. For each foot run of arch width, the weight of the

Fig. 2

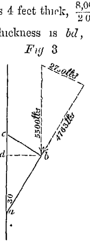


* With the present arrangements for running and closing each Terminal Branch during every alternate week it will be always possible to float a staging covered with a rough centring of straw or other compressible material under the remaining rib of each arch as the canal is rising. This would ensure every portion of the rib being fully supported, when the canal had risen to its full height.

† By Mr. James Hair, Executive Engineer, Northern Division, Ganges Canal.

half arch and superstructure may be taken at 8,000 lbs, and as the pier is 4 feet thick, $\frac{8,000}{2 \cdot 00} = 4,000$ lbs are borne by the slice of pier of which the thickness is *bd*, weight of vertical prism of masonry above *bd* may be taken at 1,500 lbs. We therefore have a vertical pressure of 5,500 lbs acting on the face *ab* which can be resolved into $5,500 \times \sin 60° = 4,763$ lbs, acting parallel to *ab*, and tending to make the joint give by sliding, and into $5,500 \times \sin 30° = 2,750$ lbs acting perpendicularly to *ab* and tending to prevent motion. Taking 0·71 as co-efficient of friction of brick on brick, and cohesion of mortar as 50 lbs per square inch,* it will be seen that the pier with portion of arch left in it is strong enough to bear very nearly $3\frac{1}{2}$ times the weight thrown on it, for $\frac{(2750 \times 0 \cdot 71) + (2 \times 7200)}{4763} = 3 \cdot 43$

Fig 3



The work has been most carefully and successfully completed by the Executive and Assistant Engineers in charge, and the alteration of a number of other bridges is now being carried out in the same manner

DINGURREE, H A B
May 29*th*, 1868

* In reality, the kunkur lime is generally found to have set into a material quite as hard as the kunkur blocks which it cements together.

No CXCVI

THE AMERICAN TUBE WELL *

Description of the American Tube Well, as used by the Abyssinian Field Force

General Description —The object of the American Tube Well is to obtain water from water bearing strata at moderate depths, without the great labour and expense in time and materials, frequently requisite in sinking an ordinary well, but it is only applicable in those situations where water can be drawn by a common suction pump, that is, within depths not exceeding about 28 feet

In these wells, a small iron tube (ordinarily a gas pipe of $1\frac{1}{16}$ inch external diameter), having a solid iron point at its lower end, is forced down by a simple driving apparatus to the water bearing stratum, thus forming a continuous steining The water is admitted to the lower end of the tube through a series of holes perforating its sides, the entire area of the holes being about half as much again as that of the internal area of the tube, and it is drawn out by a small and convenient Suction Pump attached to the upper end of the tube.

The tube being very small, is in itself capable of containing only a very small supply of water, which would be exhausted by a few strokes of the Pump, the condition, therefore, upon which alone these Tube Wells can be effective, is that there shall be a free flow of water from the outside through the apertures into the lower end of the tube When the stratum in which the water is found is very porous, as in the

* The English Agent for these Wells is Mr J L Norton, 38, La Belle Sauvage Yard, Ludgate Hill, London, E C

case of gravel and some sorts of chalk, the water flows freely, and a yield has been obtained in such situations as great and rapid as the pump has been able to lift, that is 600 gallons an hour in some other soils, such as sandy loam, the yield in itself may not be sufficiently rapid to supply the pump, in such cases, the effect of constant pumping is to draw up with the water from the bottom a good deal of clay and sand, and so gradually to form a reservoir, as it were, around the foot of the tube, in which water accumulates when the pump is not in action, as is the case in a common well In dense clays, however, of a close and very tenacious character, the American Tube Well is not applicable, as the small perforations become sealed and water will not enter the tube When the stratum reached by driving is a quicksand, the quantity of sand drawn up with the water will be so great, that a considerable amount will have to be pumped before the water will come up clear, and even in some positions, when the quicksand is of great extent, the effect of the pumping may be to injure the foundations of adjoining buildings on the surface of the ground.

The Tube Well cannot itself be driven through rock, although it might be used for drawing water from a subjacent stratum through a hole bored in the rock to receive it

Applications —Subject to these conditions these Tube Wells afford a ready and economical means for drawing water to the surface from a depth not exceeding 27 or 28 feet

The inventors are of opinion that these tubes and the means they provide for driving them, may be used with advantage in Artesian basins, but no experiments have been made in this country in driving them beyond 27 or 28 feet the inventors say that these tubes have been driven in America to a depth of 120 feet They have been driven through chalk and very hard beds of flint and gravel with great success, breaking the larger flints after a few blows and penetrating the ground in such positions at a steady rate of 12 feet an hour, in softer ground, they have driven 20 feet an hour

These Tube Wells may also be used for raising water from a pond or river for the purpose of filling troughs or reservoirs, and may be found exceedingly valuable for this purpose with an army in the field, to obviate the annoyance generally caused by large bodies of men making the water muddy, where they have to dip into it from the edge of a

stream or pond, and by horses, cattle, &c, using the same water supply as the men

These Tube Wells possess other advantages in a military point of view, the apparatus connected with them is simple and not readily put out of order, it can be easily carried, even on pack animals, the wells can be sunk very expeditiously, and, when done with, can be withdrawn from the ground with still greater expedition without being damaged in the process, so that the same tube and pump may be used repeatedly in different situations.

Description of the Tubes.—The well consists of a hollow wrought iron tube, composed of any number of lengths (ordinary gas-pipes will answer), according to the depth required. The tubes vary from 3 to 11 feet in length The water is admitted into the tube by means of six vertical rows of holes which extend up the lowest length for a height of $2\frac{1}{2}$ feet from the bottom, the holes being $1\frac{1}{2}$ inches apart vertically. The total area of the holes is about $1\frac{1}{2}$ times that of the internal area of the tube, of which the diameter is $1\frac{1}{4}$ inches, its external diameter being $1\frac{13}{16}$ inches

The lowest length or *Well Tube* is from 6 to 11 feet long, including a solid point 10 inches long, steeled at the tip, and eight-square in section, which is welded on to its lower end

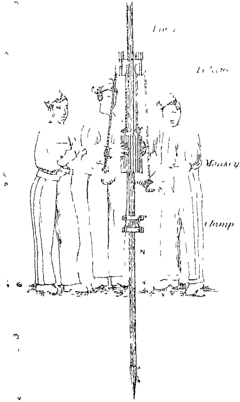
The Tube is driven gradually into the ground by means of a monkey, one length after another being added as required, until the desired depth has been reached The connection between two lengths of tube is made by means of a wrought iron collar 2 inches long, screwed over the ends of the lengths, which have screw-threads cut in them for about an inch in length, the ends of the two adjoining lengths must be made to abut against each other, and the joints should be made water tight by means of white lead.

Driving Apparatus.—The Driving apparatus consists of the *Monkey*, the *Clamp*, the *Pulleys*, and the *Extension Tube.*

The Monkey is an iron casting weighing about 75 lbs., hollow in the centre so as to slide up and down on the tube with ease, it has a couple of lugs on opposite sides to which are fastened two $\frac{3}{4}$-inch ropes, 9 feet long, for raising it

The Clamp is made to fit the tube, and is intended to receive the blows of the monkey. It is made of wrought iron, and is divided in

AMERICAN TUBE WELL



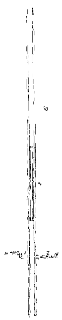
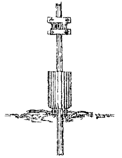
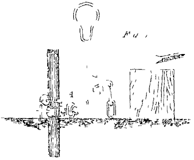


Fig 3



Plan of Link



two halves, so when placed on the tube it can be firmly secured to it by four screw bolts, the nuts of which should be tightened as much as possible, so that the clamp when struck by the monkey shall not slide on the tube, but carry it down with it, in yielding to the force of the blow The inner surfaces of the clamp where hollowed to fit the tube are steeled, and rough screw-threads are cut on them, so as to assist in giving the clamp a firm hold on the tube The top of the clamp should also have a steeled surface on which to receive the blow of the monkey.

The Pulleys are hung on to a cross piece which can be clamped to the tube by means of two thumb-screws The ropes from the monkey are rove through these two pulleys.

The Extension Tube is simply a 5-feet length of the same description of pipe, with a 2-feet length of smaller pipe brazed securely into one end, leaving one foot of its length projecting The external diameter of the smaller tube should be nearly equal to the internal diameter of the larger tube, so that when placed in it, the lengthening shall be tolerably firm

Fig 1, *Plate,* XXIX, is a section showing the apparatus as arranged for driving, and *Fig* 2, shows the application of the extension tube.

Driving the Well The position for a well having been selected, a perfectly vertical hole is made in the ground with a crow-bar as deep as is convenient, into this hole the well tube (the clamp, monkey, and pulleys having been previously placed on it) is inserted

The Clamp is then screwed firmly on to the tube from 18 inches to 2 feet from the ground (according as the soil is difficult or easy,) each bolt being tightened equally, so as not to indent the tube

The Pulleys are next clamped on to the tube at a height of about 6 or 7 feet from the ground, the ropes from the monkey having been previously rove through them

The Monkey is raised by two men pulling the ropes at the same angle (the nearer to the vertical the better), they should stand exactly opposite each other, work together and very steadily, so as to keep the tube perfectly vertical and prevent it from swaying about while being driven. If the tube shows an inclination to slope towards one side, a rope should be fastened to its top and kept taut on the opposite side, so as gradually to bring the tube back to the vertical When they

have raised the monkey to within a few inches of the pulleys, they lift their hands suddenly, thus slackening the ropes and allowing the monkey to descend with its full weight on to the clamp The monkey is steadied by a third man who also assists to force it down at each descent This man likewise from time to time with a pair of gas tongs, turns the tube round in the ground, which assists the process of driving, particularly when the point comes in contact with stones

Particular attention must be paid to the Clamp, to see that it does not move on the tube, the bolts must be tightened up at the first appearance of any slipping

When the clamp has been driven down to the ground, the monkey is raised off it, the screws of the clamp are slackened and the clamp is again screwed to the tube about 18 inches or 2 feet from the ground To prevent the monkey slipping while this is being done, the pulley men will take a hitch, with the running parts of their ropes, round the standing parts below the pulleys. When the clamp has been screwed on again, the monkey is lowered on to it, and the pulleys are then raised until they are again 6 or 7 feet from the ground. The driving is then resumed as before

When the tube has been driven so far into the ground that its upper end is not sufficiently high to carry the pulleys, the small end of the extension tube is inserted into the Well Tube, and the pulleys clamped on to it at the proper height

The driving is continued as before, until but 5 or 6 inches of the Well Tube remain above the ground, when the clamp, extension tube, monkey, and pulleys, are removed, and an additional length of tube screwed on to that in the ground This is done by first screwing a collar on to the tube in the ground, and then screwing the next length of tube into the collar till it butts against the lower tube, a little white lead must be placed on the threads of the collar before the ends of the tubes are screwed into it

The driving can thus be continued until the Well has obtained the desired depth Soon after another length has been added, the upper length should be turned round a little with the gas tongs, to tighten the joints, which have a tendency to become loose from the jarring of the monkey. Care must be taken after getting into a water bearing stratum, not to drive through it, owing to anxiety to get a large supply

from time to time, and always before screwing on an additional length of tube, the well should be sounded (by means of a small lead attached to a line,) to ascertain the depth of water, if any, and character of the earth which has penetrated through the holes perforated in the lower part of the well tube. As soon as it appears that the well has been driven deep enough, the pump is screwed on to the top and the water drawn up. It usually happens that the water is at first thick and comes in but small quantities, but after pumping for some little time, as the chamber round the bottom of the well becomes enlarged, the quantity increases and the water becomes clearer.

Cleaning Apparatus.—When sinking in gravel or clay, the bottom of the Well Tube is liable to become filled up by the material penetrating through the holes, and before a supply of water can be obtained this accumulation must be removed by means of the cleaning pipes.

The cleaning pipes are of small diameter (½-inch externally,) and the several lengths are connected together in the same way as the Well Tubes, viz.—by collars screwing on over the adjoining end of two pipes.

To clear the well, one cleaning pipe after another is lowered into the well, until the lower end touches the accumulation, the pipes must be held carefully, for if one were to drop into the well it would be impossible to get it out without drawing the well. A pump is then attached to the upper cleaning pipe by means of a reducing socket provided for the purpose, the lower end of the cleaning pipe is then raised and held about an inch above the accumulation by means of the gas tongs. water is next poured down the well outside the cleaning pipe, and being pumped up through the cleaning pipe brings up with it the upper portion of the accumulation, the cleaning pipe is gradually lowered, and the pumping continued until the whole of the stuff inside the Well Tube is removed. The pump is then removed from the cleaning pipe, and the cleaning pipes are withdrawn piece by piece, and finally the pump is screwed on to the upper end of the Tube Well which is then in working order.

It is advisable when several wells have to be sunk to keep one pump specially for the purpose of cleaning out the wells, as the grit, &c., at first pumped up, is liable to damage the valves. When all the wells have been sunk, the valves of this pump should be examined, and if necessary repaired, when it may be used for a well if required.

Drawing the Well.—The Tube Well, when required no longer, can be drawn by either of the following methods:—

1st.—The monkey is placed on the tube with its lower end upwards, and the clamp screwed on about 1 foot above it. The monkey is then raised sharply, and by striking the clamp, gradually starts the well, the position of the clamp is lowered from time to time as required (*Fig.* 3). This method has always been found to succeed, but is not quite so rapid a process as the following; it is to be observed, however, that these latter occasionally fail.

2nd.—A short length of chain is passed twice round the tube close to the ground, and one end passed through a large ring in the other end (*Fig.* 4). The end of the chain is then put through a movable stoppering link which can be made to grip any link desired. A lever or hand-spike is next inserted into the stoppering link, and borne down upon some convenient fulcrum placed under, and the Tube Well lifted. When another lift is required the chain is slipped down the tube to the ground, the lever again inserted, and the lifting proceeded with.

3rd.—In very soft ground the well may be drawn by simply turning it round with the gas tongs, at the same time lifting it upwards.

Men, Tools, &c.—Five men are required for driving a well quickly, allowing two men in two reliefs for working the monkey, while the fifth, a non-commissioned officer, steadies the monkey, attends to the clamp to see it does not slip on the tube, and alters its position, and that of the pulleys as required. The two men not working the monkey will prepare the additional lengths of tube, and fix them on as required.

The following table shows the stores, with weights of the articles, forming one complete set of Driving Apparatus, as arranged for mule transport:—

No. I MULE

*	1 Monkey with Ropes,	81 lbs.	101	Total Load, 202 lbs.
	1 Crow Bar, 5 feet long,	20 „		
*	1 Wrought Iron Clamp,	26 „	101	
*	1 Pair of Pulleys,	6 „		
*	1 Extension Tube, 6 feet,	16 „		
	1 Wrought Iron Clamp, (extra)	26 „		
	1 Set Cleaning Pipes, viz., 4 6 feet, 1 3 „ lengths of $\frac{1}{2}$in. pipes, 1 Reducing Socket,	27 „		

The stores marked thus (*) can be carried by two men on the Extension Tube.

No II MULE

	1 Water Barrel (3 gallons, filled)		40 lbs	106	212lbs
	1 Leather Bucket,		5 „		
	1 Pump for Cleaning,		25 „		
Available for Tent or Personal necessaries,			36 „		
Packed in a box	4 Gas Tongs, (½, ¾, 1¼, 1½ inches,		16 „	106	
	2 Spanners for Clamps,		8 „		
	1 Pair Stocks and Dies,	13lbs	12oz		
	1 Set of Tube Cutters,	7 „	8 „		
	1 File half round, 10 inches,		10 „		
	1 Lifting Chain and Stoppering Link,		3 lbs		
	1 Gallon Tin of Oil,		10 „		
	1 Oil Can with Trap nozzle,	1lb	4oz		
	1 Tin of White Lead,		10 lbs		
	1 Set of Ropes (extra),		1 „		
	10 Spare Nuts and Screws for Clamp,		19 „		
	1 Plumb-bob and Line, (30 feet),		6oz		
	2 Iron Caps,	1lb	12oz		
	2 Spare Collars,	1 „	8 „		
	2 Spare Washers for Lower Valve,		1 „		
	5 Leathers for Well Pumps,		3 „		
	2 Spare Lugs for Monkey,		1 lbs		
	Box with hasp and lock,		11 „		

The following is the list of Tubes, &c., required for two Tube Wells as arranged for mule transport —

ONE WELL	1 Well Tube, 6 feet long, $1\frac{13}{16}$ inches diameter with solid Iron Point, steel tipped, 10 inches long,	22 lbs	107	214lbs
	3 6 feet lengths $1\frac{13}{16}$ inches diameter,	18 „		
	1 3-feet length $1\frac{13}{16}$ „ „	8 „		
	1 Pump	25 „		
	5 Collars	4 „		
SECOND WELL—The same as above			107	

The following in an extract from a letter which appeared in the *Delhi Gazette* of the 23rd May, on the result of the working of these Wells —

At Zoolla, where search for water was first made, the Norton pump on being driven, failed to bring up anything but the fine particles of the soil, the reason being that the water lay at too great a depth beneath the surface

At Koomaylee, at the entrance to the Senafe Pass, one of Norton's pumps was driven successfully, and though the amount of the water obtained by it was small, and all further attempts to drive other similar pumps were fruitless, by reason of the boulders and rocks in the way, yet the success was of value, as it showed where water existed

At Undle-Wells, in the Senafe Pass, distant from Zoolla 38 miles, great difficulty was experienced about water For some time, a single Norton pump served to supply the station At length, the wells which had been commenced were finished, and in one which was lined with stone set in lime, a Bastier chain pump was fixed Though the water never rises higher than four feet, there is no deficiency of supply; the depth required to work the Bastier is three feet

At the foot of the ghat leading to Senafe where a depot of stores was to be established, and water consequently, required, the driving of our Norton pumps success-

fully as at Koomaylee was of service, in showing the position of the water, apart from the advantage of obtaining in a few minutes a supply, limited though it was from the scantiness of the source. Here again only one pump was ever driven with success, though seven distinct attempts were made. Now a well has been sunk in, and that with the Norton pump, gives the requisite supply.

At Senafe, on the highlands of Abyssinia, when the troops first arrived, there were only dirty pools, the vestiges of what had once been a stream. From these, teeming with frogs and tadpoles, the troops had to drink. Soon, though, wells were dug; but the water from exposure to the sun and contact with the rich clay earth, became ere long unwholesome; time did not permit of digging deep and lining the well with stone. In February, six Norton's pumps were driven into the soil at Senafe and all with complete success; these supplied drinking water to the garrison. The water for animals was supplied similarly by five Norton's pumps driven in rear of the trough. This supply was supplemented by the water of two springs which was led by ducts into the trough. A flood occurred here last month, which polluted the reservoirs, from which, by a subsequent arrangement, the trough was fed by washing into them the filth of the transport train lines, unhappily situated above the sources of the water.

This pollution necessitated an entirely new and immediate arrangement for the supplying of water; and Norton's pumps, from the readiness with which they could be applied, afforded an easy means of obtaining water in another part of Senafe, remote from danger of flood, and at the same time gave leisure for the construction of permanent arrangements.

It has been found that one Norton pump is required for a trough 16 feet long, 10 inches wide, and 9 inches deep; and that it answers well on ordinary occasions, but the pressure, on the arrival of a large convoy, becomes very great, unless those employed in pumping are good men. Besides, the expenditure of labor, one man to each trough is excessive; and hence, when time permits, arrangements are made for supplying water with more powerful pumps. But the Norton pumps are excellent to start with and to fall back upon in case of need. Thus, on this occasion, the Norton's having supplied water for more than three weeks, gave way to a Bastier-chain-pump, which was fixed in a well at one extremity of a trough, ninety-six feet long. It should here be mentioned, that the diameter of the Norton pipe is one and a half inches; that that of the pump-cylinder is three inches; that the length of stroke is six inches.

The Bastier-chain-pump deserves some notice.

It consists of a pipe three inches in diameter, in lengths of five feet, all capable of being bolted strongly together. Across the mouth of the well is an iron wheel, two feet in diameter, over which passes a chain furnished with suckers or discs of gutta-percha at intervals of three feet, the interval depending upon the diameter of the wheel. This chain passes into the water, enters a bell-mouthpiece bolted to the end of the pipe, and is guided by it into the pipe up which it passes to the wheel. The wheel being turned, it draws up the chain and a column of water resting on the suckers, which at the lower part fit the pipe very tightly. The water is thrown up into a cistern, surrounding the head of the pipe, from which it is conveyed away when it may be required.

As may be imagined, the flow is very equable and at the same time great, 600

gallons per minute. The pump requires four men to work it, if the labor is to be for any length of time.

It is by no means a portable pump, and in erection, it is one demanding much care, labour and consideration of true level.

The water that is drawn up by the Norton-pump is perfectly pure for drinking; no pollution can touch it, and it is invariably cold, a blessing mightily to be appreciated under a hot sun. It has been said that they are easily broken. To some extent the assertion is true. But it may safely be affirmed that the native of India would break anything of such a nature, from his ignorance of the way in which to use it, and utter indifference to what happens, so long as his wants are supplied.

The bolts on which the handle works and that connecting the piston rod with the lever handle, are too easily worn through, and the cast iron arrangement, by which the handle could be turned right or left, or directly behind the spout, was too liable to be snapped asunder by a jar, rendering the pump, perhaps at an important time, useless.

On another campaign, doubtless, if wanted, an improved form of pump head will be given, providing greater strength, greater stroke, and, consequently, greater delivery of water. But as it is, those who have benefited here by Mr. Norton's ingenious invention, cannot but feel grateful to him.

Nothing could have happened more opportunely than the invention and its application on this campaign.

It should be mentioned, that while the principle is all that could be desired, the construction is not such as would have been designed for the use of an army in the field, but only such as might be fit to meet the necessities of one desiring to have a source of water of this nature in his garden.

The material of the pump—cylinder and its parts is cast-iron. The weight of the pump-head, with four 6 feet and one 3 feet lengths, is 60lbs., that of the ram (51lbs.) with clamp and necessary tools, 85lbs. Hence the total weight is 145lbs., and this is rather below the mark.

Such a weight is an objection. A pump of much less weight might be made of steel, on this principle; but the satisfaction, where circumstances would permit, of having such a pump in the enclosure around one's house would be very great, since the certainty of obtaining pure and cold water would be secured, and the uncertainty and vexation of filtering, cooling, &c., avoided.

SENAFE, 28*th April*, 1868.

H. WILBERFORCE CLARKE,
Lieutenant, R. E.

No CXCVII

MOTION OF WATER IN CANALS

Report submitted to the Academy of Sciences, at Meetings held on the 27th July and 3rd August, 1863, on a Memoir by M BAZIN, *on the Motion of Water in open channels* *Committee* —M M. DUPIN, PONCELET, CLAPEYRON, MORIN, *Secretary* [*Translated from the French.*]

ENGINEERS who have to deal with questions relating to the discharge of channels and conduit pipes, have long been aware that the formulæ deduced by Prony from a limited number of observations, made under dissimilar circumstances, were only applicable to particular cases

On the one hand, their complicated form renders their application tedious, even with the aid of tables, and on the other, the influence of the nature of the sides or bed of the conduit, which these formulæ do not take into account, has been so clearly demonstrated through the able researches of the late M Darcy, on the motion of water in pipes, that it was very necessary that further enquiries should be instituted for the purpose of ascertaining the laws of this influence in the case of channels

As far back as the year 1854, in a report approved by the Academy on the earlier works of M. Darcy on conduit pipes, we solicited the good offices of the administration on behalf of the researches which this able Engineer had conducted, and which he proposed to extend to the subject above mentioned

The support of the Minister of Public Works was freely given to the undertaking, and M Darcy also secured the co-operation of several

eminent Engineers M Baumgarten, Chief Engineer in the "Ponts et Chaussées' gave him the aid of a long experience acquired on the Rhine, and M Ritter, Hydraulic Engineer of the department "Côte d'Or" also placed his services at his disposal But M Darcy had not estimated the extent of the task he had imposed on himself, after his strength had become impaired by a long service Moreover M Baumgarten and M Ritter were called away to other duties, and were obliged to leave M Darcy in 1856, at the very time when the preliminary measures preparatory to the commencement of the experiments, had been carried out

It was reserved for M Bazin, whose services M Darcy obtained at this juncture, to assist in the undertaking in the first instance, and eventually on the death of that much lamented officer in 1858, to succeed to the entire charge of it It thus devolved on him to collate, complete and describe, the results of the vast number of delicate experiments which had been conducted, and to deduce, for the guidance of Engineers, the important consequences to which they led

The work which we now lay before the Academy thus embodies results which have been obtained by the labors of several Engineers The investigation was organized and initiated by M Darcy, and carried on under his direction up to the time of his death, but the execution of a large proportion of the experiments, the analysis of their results, and the scientific deductions which are drawn from them, and which are set forth in M Bazin's memoir with remarkable clearness, must be considered as the work of that officer alone

M Bazin's memoir is divided into four principal sections, containing an account of —

1 Experiments on canals, in a state of uniform motion
2 Experiments on the distribution of the velocities
3 Experiments on variable motion.
4 Experiments on the motion of waves.

The great extent of these researches, which are described in four manuscript folio volumes, accompanied by forty plates admirably drawn by Assistant Engineer M Chopin, has obliged us to entrust the examination to two members of our committee, by whom the partial report now submitted, namely, that which relates to the motion of water in channels with a uniform regime, has been prepared.

On the Uniform Motion of Water in Channels

Before analysing the more important results of a long series of observations which were commenced in 1855 and were only terminated in 1862, we consider it necessary to give a brief description of the arrangements which were made to insure accuracy, both as regards the observations themselves and the consequences which were deduced from them

General arrangements —In carrying out the experiments with a view to assimilate the conditions under which they were observed as far as possible, to those under which any rules which they should lead to would be applied in actual practice, M Darcy opened out a channel from reach No 57 of the Canal de Bourgogne, carried it parallel to the canal for a distance of 450 mètres, and then turned it into the river d'Ouche, at a further distance of 146½ mètres This channel was revetted with poplar planks sustained on a framework, and was 2 mètres wide by 0 95 mètres deep in the clear It was incased in a layer of puddle of a very impermeable quality, and its dimensions were such as to allow of additional planks being attached on the inside, for experiments on various slopes and sections of the forms proposed for investigation.

Head works —The water for the supply of the channel was drawn from the canal at 157 mètres below lock No 56, by means of a sluice of four vents, each 1 mètre wide, and 0 40 mètre high , but it was soon perceived that in order to obtain a regular and uniform flow in the channel, it was necessary to form a basin or distributing reservoir between it and the head sluice, and to construct a second sluice with a greater number of small vents, for the direct supply of the channel

M Darcy accordingly constructed a second sluice with 12 vents, each 0 20 by 0 20 mètres, with frames and paddles of copper, and with their form and proportions in as close accordance as possible with those for completely contracted orifices, the discharge of which has been so fully investigated by M. M Poncelet and Lesbros in their valuable experiments on the flow of water through orifices

It should, however, be mentioned that, local peculiarities and the short intervals between the vents of the sluice having caused some discrepancies in the co-efficients, it was found necessary to carry out some special experiments to determine the precise value to be given in each case which had to be considered

These experiments were executed with facility, and the accuracy of their results leaves nothing to be desired, while the considerable size of the receiving channel allowed of a correct determination being made of the volume of water drawn off. Besides the ulterior use to which the results thus obtained were applied, in the special researches described in the present work, they furnish useful data to engineers for determining the discharge from a series of vents coupled together.

Means employed to determine the velocity at different points in the same cross section.—The law of the distribution of the velocities in different points of the same section is one of the most delicate and most disputed questions in hydraulics, and as its solution can only be determined by experiment, the discovery of the proper kind of instrument for carrying on the observation is a matter of great importance. It has, consequently, long engaged the attention of engineers. It was however, reserved for the late M Darcy to succeed, by well conceived and excellently matured improvements of an apparatus known under the name of "Pitot's tube," in obtaining a convenient and accurate instrument.

It is well known that Pitot presented the Academy with the instrument which bears his name in 1732, and that it consisted of a long wooden bar of triangular section, in one side of which were attached two glass tubes, one tube was curved horizontally at the lower extremity the other, on the contrary, descended vertically as far as the curved portion of the first. Pitot was of opinion that this apparatus, when exposed to a stream, would give, for the difference of level between the two columns of water in the tubes, the height due to the velocity of the stream at any point, and that it would be easy to deduce therefrom the velocity sought for, by means of the expression $V^2 = 2gh$, h being the observed difference of level.

The idea was simple and ingenious, but notwithstanding the trials of Du Buat and other experimenters, various circumstances combined to prevent its furnishing a convenient and sufficiently certain method of determining the velocity of the different filaments in any section of a stream. It was reserved for M Darcy to surmount these difficulties by a number of ingenious arrangements to which he had been led in the course of his investigations, and which are described in his Report

on the "Motion of Water in Conduit Pipes," to which we refer for a description of the instrument

In the tubes employed by M Darcy the elevation of level, h', in one, and the lowering, h'', of level in the other, above and below the general level of the stream, would together give

$$V = \mu \sqrt{2 g (h' + h'')}$$

the velocity of the fluid filament at the extremity of the horizontal tube, if the co-efficient μ were in the first instance determined The above formula is made use of by M Darcy, but his observations were facilitated by a number of ingenious arrangements, which are described in M Bazin's report

Co efficient of the hydrometric tube—After the intimation we have given of the improvements introduced by M Darcy in Pitot's tube, we consider it necessary to explain the procedure by which its accuracy was verified, to confirm the confidence which he and his colleagues placed in its results For this purpose, three several tests were applied

1 By measuring the surface velocity by means of floats, and comparing it with the velocity obtained by the tube

2. By moving the instrument with a known velocity in still water

3 By measuring with the tube the velocity at a number of points in the transverse section of the stream, and by comparing the discharge thus obtained with the actual known discharge These three methods which were completely independent of each other gave the following values of μ in the formula, the

First mean of 92 trials,			$\mu = 1\ 007$
Second,	32	"	$\mu = 1\ 034$
Third,	31	"	$\mu = 0\ 993$

M Bazin remarks that the results obtained from the motion of a boat would be somewhat in excess of the true values of the co-efficient in consequence of the form of the bows, and that as the instrument would have a similar effect, the definitive value of the co-efficient was taken as the mean of the first and third values, that is $\frac{1\ 007 + 0\ 993}{2} = 1{\cdot}0$

The value of the co-efficient must depend on the form of the instrument, and, if constant for one, it will vary for another, according as the arrangements and the dimensions of the orifices may be different.

After this preliminary explanation of the means employed by M

Darcy and M Bazin for conducting their experiments, we proceed to a consideration of a highly important question, which forms the principal object of the researches described in M Bazin's memoir, namely, *the resistance of the sides and bed of canals and rivers to the motion of water* under a uniform regimen We know that Prony's formula

$$RI = a\,U + b\,U^2$$

in which R is the hydraulic mean depth, I the fall in unity, U the mean velocity, and a and b numerical co-efficients, was founded on a small number of experiments which were carried on under circumstances which properly did not admit of comparison, unless to a very limited extent

Writers on Hydraulics have long desired to effect an improvement on this formula, and many Engineers and the Italian authors generally have reverted to the formula proposed in 1775 by M Chezy, namely $RI = b\,U^2$, in which b is generally taken $=$ ·0004 M de Saint Venant substitutes the exponent $\frac{21}{11}$ for 2 in the same formula, leaving the co-efficient b nearly the same as before

But these, and other, writers on hydraulics have continued to admit with Du Buat, that the nature of the sides or the lining of the channel has no sensible influence on the resistance opposed to motion, which however could not be accepted as even approximately true, for M Darcy's experiments on the flow of water in pipes had proved that the condition of the sides and the nature of the material of which they are formed have a very marked influence on the resistance If, therefore, for substances so smooth as those of the interior of pipes, it was incontestibly proved that the resistance opposed by them to the motion of fluids, essentially depended on their condition and on their nature, it was evident, *a fortiori*, that this would hold good with regard to the motion of water in canals and rivers, since their beds presented much greater irregularities than in the case of pipes *

To show the inaccuracy of the received formulæ and to obtain some idea of the errors they may give rise to, M Darcy in the first instance requested M Baumgarten to make some preliminary experiments on

* *Note by Translator.*—The late Col Dyas was quite alive to the necessity of taking into account the resistance of the bed due to the nature of the material In a memo, dated 20th November, 1865, he stated his opinion on this point to the following effect —

"The results of actual observations on high velocities in shingle and boulder paved channels, and in channels lined with brickwork, have long since convinced me that the effects due to the nature of the material in which a channel is formed are by no means to be neglected "

the Marseilles canal, which presents a great diversity of section, and of which the sides and bed are lined with various kinds of material These experiments which were carried out in May 1855, showed that on a portion of the aqueduct of Roquefavour where the bed was very even, and the sides were formed of good brickwork, the value of the expression $\frac{RI}{U^2}$ was hardly the half of that which the old formula would give, and that, on the other hand, on a portion of the canal where the sides were of earth, the value of $\frac{RI}{U^2}$ was nearly doubled

A variety of other experiments which were executed by M Bazin, in 1856, on rectangular canals with a uniform fall, but with the sides and bed formed of different materials, namely, plaster, bricks laid flat, small gravel from 0 01 to 0 02 mètres in diameter, and coarse gravel 0 03 to 0 04 mètres in diameter, and imbedded in mortar, showed that, in proportion as the discharge and velocity were increased, the values of the co-efficient $\frac{RI}{U^2}$, instead of varying from only 000327 to 000389, as Prony's formula would indicate, decreased to the following extent —

Plaster coating—from		000242	to	000172
Planks,	„	000411	to	·000229
Bricks,	„	000408	to	000277
Small gravel,	„	·000882	to	000472
Coarse do ,	„	001454	to	000661

Another experiment made on a canal with a semicircular section showed that even between a coating of plaster mixed with one-third sand, and a coating of fine plaster without sand, there was a difference of resistance in favor of the latter, which, with the same fall, would increase the discharge in the proportion of 1 to 1 13 or by about $\frac{1}{7}$th.

It thus became evident, by these comparative experiments, that the nature of the lining has an influence on the resistance to the flow of water in channels, even greater than M Darcy had found to be the case in pipes.

Other experiments, not less conclusive, were carried out on the small channels from the Canal de Burgogne, under conditions similar to those of ordinary channels The results proved —

1. That the resistance on these channels was always considerably higher than the values obtained by Prony's and Eytelwein's formulæ

2. That the value of the co-efficient $\frac{RI}{U^2}$ diminished as the discharge

increased. It was also discovered by means of two experiments of this series, that a coating of moss only, on the surface of a retaining wall, doubled the amount of the resistance.

In the face of these great variations in the value of a co-efficient which hydraulic authors had previously considered to be nearly a constant quantity, and the diverse conditions on which it appeared to depend, it seems to be out of the question to seek to discover the law which determines its value, by purely physical or mathematical investigations. We can only confine our attention to the principal cases which are liable to occur most frequently in practice, and endeavour to connect the results by formulæ of interpolation, which will give a sufficient degree of accuracy for practical purposes.

Du Buat had already remarked that the co-efficient $\frac{RI}{U^2}$ diminished, as the hydraulic mean depth, R, and the velocity, increased, but the limits within which he had the means of varying his data were too restricted to permit of his determining the law of this change.

On the other hand, since an examination of the various sets of experiments described in M. Bazin's Memoir, shows that the value of the co-efficient appears to tend to a certain fixed limit, it follows that by terming this limit a, the value of $\frac{RI}{U^2}$ would be expressed thus—

$$\frac{RI}{U^2} = a + f(R, U)$$

M. Bazin has compared the results of the experiments with the two most simple forms of the unknown function, by supposing successively—

$$f(R, U) = \frac{\beta}{R}, \quad f(R, U) = \frac{\beta}{U}$$

and by selecting for the comparison, five series of experiments on which the fall I in unity was the same and equal to 0.0049, and of which the transverse sections were nearly identical. In these experiments, the velocities were varied so as to comprise within their limits any cases which were likely to be applicable in practice for calculations connected with the supply of mill channels and navigable canals.

On representing all the results of the observations by diagrams, the values of $\frac{RI}{U^2}$ being taken in each cases as ordinates, and those of $\frac{1}{R}$ and $\frac{1}{U}$ as abcissæ, M. Bazin ascertained that for the same fall of ·0049 and the same width of channel, the points thus determined were in both cases in nearly straight lines, of which he has thus obtained

the equation for each of the five canals on which the experiments were made, while the formulæ which do not take into account the nature of the lining of the channel, namely, those of Prony, Eytelwein, and Saint Venant, being also represented by diagrams, it was easily perceived that none of them yield results in accordance with the observations, and that they ought all therefore to be given up

Influence of the fall I —But, if the five sets of experiments above mentioned, which were made on canals having all the same fall and the same cross section, and of which the nature of the sides and bed alone varied, showed the necessity of taking the influence of the latter into account, and, if the results might be equally well represented by either of M Bazin's two formulæ, by giving the proper value to the co-efficients, it was further necessary to ascertain if one or other of the formulæ answered for different falls and cross sections. The object of the experiments executed by M Bazin, in 1858-59, after the death of M Darcy, was to determine this point

To avoid complicating the question with accidental influences, and it having already been explained that, apparently, very slight differences in the nature of the sides would have an effect, it was decided to operate on three different rates of fall, namely, 0015, 0059, 00886 in unity, and on canals formed of planks, with a rectangular cross section, and all about 1 96 mètres wide throughout For the purpose of observing the effect of changing the degree of roughness of the sides and bed, but with the same kind of material, it was arranged to use wood in every case, and to produce artificial irregularities of surface on some of the canals experimented on, by attaching strips or laths, 0 027 mètres wide by 0 010 metres thick, at intervals first of 0 01, and afterwards of 0 05, mètres from each other By these means nine sets of experiments were obtained on three canals, lined with the same kind of material in each case, but with different falls

In calculating, for each series, the value of the co efficient $\frac{RI}{U^2}$, M Bazin found that it always diminished as the discharge and velocity increased, and that for the same discharge, it increased, but very slowly, as the fall and velocity, or, what is the same thing, as the depth of water decreased. Thus between a discharge of 0 100 and 1 236 cubic mètres, per second, the value of $\frac{RI}{U^2}$ varies as follows for a canal lined with

planks—from 0 000420 to 0 000226, with a fall of 0 0015 for a canal with laths at intervals of mètres 0 01—from 0 000651 to 0 000338 and for a canal with laths at intervals of mètres 0 05—it varied from 0 001379 to 0 000659

We are therefore led to the conclusion that the formula $\frac{RI}{U^2} = \alpha + \frac{\beta}{U}$ which is nothing more than the binomial formula adopted by Prony and Eytelwein, and heretofore generally made use of, should be given up entirely, and that the formula $\frac{RI}{U^2} = \alpha + \frac{\beta}{R}$ is much better suited to yield results in accordance with observation, as regards canals of which the sides and bed are under the same conditions, but which have different rates of fall

Influence of the form of the transverse section of channels —Canals are most commonly of a rectangular or trapezoidal section, but in some cases the depth may be great in proportion to the width, and in the latter, the form may approximate to a triangle Masonry conduits are also in some cases in the form of a segment of a circle

The experiments relating to the influence of the form of cross section, and of which the results are described in M Bazin's work, were executed—

1 On three canals lined with planks, of rectangular cross section and 1 197, 0 80, and 0 48 mètres wide

2 On two canals of a trapezoidal section, one, 1 mètre wide at sole, and with sides inclined at 45° to the horizon, the others, 0 945 mètres wide at sole, and with one side vertical and the other inclined at 45°

3 On a canal lined with planks, of triangular section, and with sides inclined to the horizon at an angle of 45°

The six series of experiments which were executed on these canals with velocities ranging from 0 73 to 2 40 mètres the second, all tend to prove that the form of the transverse section had so slight an influence as to render it unnecessary to take it into account in practice The circular form of section, however, owing to the continuity of its profile, appears to cause, all other conditions being the same, a sensibly smaller resistance, than is offered in the case of those of an angular section, a fact, which justifies the common practice of giving the beds of drains a nearly circular form.

Small Channels.—For small channels with a considerable fall, such

as those used for irrigation, and which, in consequence of the growth of weeds, or irregularities of the bed, offer a great resistance, although the velocity may not exceed one mètre per second, the value of $\frac{RI}{U^2}$ does not seem to follow the same law as in the case of large canals and as M Darcy had observed with regard to conduit pipes, when the velocity was very low, it is the value of $\frac{RI}{U^3}$ which appears to be constant for the same fall, but to increase as the fall is increased As this case has not an important bearing on practical questions, we do not consider it necessary to extend our remarks upon it

Experiments on the subsidiary channels (rigoles) of the Canal de Bourgogne —After having investigated the results of various experiments which were made with the view to ascertain the law governing the resistance of the bed in different cases, M Bazin proceeds, in the 3rd Chapter of his memoir, to collate the results of a number of experiments which were carried out on the subsidiary channels of the Canal de Bourgogne, and to attempt to represent them by formulæ which should be sufficiently exact for the wants of Engineers

Surplus channel from the Grosbois reservoir Two series of experiments were made on this channel, which is lined with rubble masonry pointed (moellons rejointoyés en ciment), and presents a very even surface It is 1 80 mètres wide at sole, and the sides are nearly vertical, the batter being about $\frac{1}{10}$th the bed was covered with a slight muddy deposit The mean velocity ranged from 2 757 to 6 429 mètres, which are probably higher velocities than have ever been subjected to experiment The surface velocity rose as high as 9 16 mètres per second, the fall along the portions of the channel examined were 0 037 to 0 101 per mètre

A diagram of the results showed that they may be represented with sufficient accuracy by the following formulæ —

$$1 \quad \text{Fall } 0\ 037\,, \ \frac{RI}{U^2} = 0\ 000256 + \frac{000053}{R}$$

$$2 \quad \text{,,} \ \ 0\ 101\,, \ \frac{RI}{U^2} = 0\ 000309 + \frac{000040}{R}$$

notwithstanding the apparent dissimilarity of the two, which is caused by the influence of the fall on the value of the coefficients, they give values of $\frac{RI}{U^2}$ which very nearly correspond

The fall of canals seldom exceeds 0 037, and hardly ever 0 101, in unity, and we may therefore assume that formula 1 will be generally applicable to channels which are revetted with masonry in the manner above described

Practical formulæ —If a consideration of the numerous experiments described by M Bazin shows that the binomial formula $RI = aU + bU^2$ adopted by Prony and Eytelwein, as well as any formula with a constant co-efficient independent of the nature of the lining of channels or of the fall, are not capable of representing the results of observation, it is equally true that the formula $\frac{RI}{U^2} = a + \frac{\beta}{R}$ proposed by M Darcy and tested by M Bazin, though more nearly exact, can yet only correspond with observation, when the values of the co efficients a and β are altered to suit each particular case

Now the nature and condition of the bed of a channel, and the constantly varying quantity of weeds with which it may be covered, are so many independent causes, which it is impossible for any theory or any formula to take into account. The most that can be done is to limit the number of special cases to be considered, so as to comprise those which present similar conditions to the cases which have to be dealt with in ordinary practice, and to endeavour to deduce from the mass of experiments, such practical formulæ as will secure a sufficient degree of accuracy for common usage

To this end, and with a view to combine the results of former observations with the new ones, M Bazin, after first pointing out that Du Buat's experiments were conducted on small wooden troughs, and that they formed the basis of Prony's formula, while on the other hand, the German observers carried on their experiments mostly on large streams, proceeds to classify the different channels according to the nature of their beds and sides He distinguishes four main classes among which he groups all the observations, these are as follows —

1	Bed and sides very even (fine plaster, carefully planed planks, &c)	
2	„	even (cut stone, brickwork, planking, ordinary mortar, &c
3	„	slightly uneven (rubble masonry.)
4	„	uneven (earth.)

In this classification, only channels of a rectangular or trapezoidal

section are included From an analysis of the results of the experiments which can reasonably be distributed among the four types of channel above described, M Bazin has deduced the following practical formulæ

1st, type, bed and sides very even,		$\frac{RI}{U^2} = 0\ 00015 \left(1 + \frac{0\ 03}{R}\right)$
2nd	„ „ even,	$\frac{RI}{U^2} = 0\ 00017 \left(1 + \frac{0\ 07}{R}\right)$
3rd	„ „ slightly uneven,	$\frac{RI}{U^2} = 0\ 00024 \left(1 + \frac{0\ 25}{R}\right)$
4th	„ „ earth,	$\frac{RI}{U^2} = 0\ 00028 \left(1 + \frac{1\ 25}{R}\right)$

(For values of these formulæ in English measurements *see p* 294*)*

M Bazin, having then drawn a diagram of the straight lines of which the above formulæ express the equations, and having entered the whole of the results of both old and new experiments, arranged under one or other of the four classes of channel, shows that all their results may be represented with a sufficient degree of accuracy by the corresponding formula It is certainly remarkable that one of the figures in the diagram, which represents the observations with the greatest accuracy, is the straight line to which are referred the results of experiments by Du Buat on earthen channels, namely, the canal du Jard, and the river Hayne, those by Funk on the Weser, by M Baumgarten on the Marseilles canal, those on the Seine carried on in 1851-52 by M Villevert under the direction of M Poirée, Engineer of the Ponts et Chaussées, and in 1852-53 by M Bonnet, under the direction of M. Emmery, Engineer Ponts et Chaussées, on the Saone, in 1858 59 under the direction of M Leveillé, Engineer Ponts et Chaussées, and finally those of the six series of special experiments executed by M Bazin on the Chazilly and Grosbois channels of the Canal de Bourgogne *

Ratio of mean to maximum velocity —Another very important inquiry as regards practical operations, is the determination of the ratio that exists between the mean velocity, U, of a stream, and the maximum velocity, V, obtained by direct observation, as a rule, by means of floats. In most cases this method has to be employed in gauging streams, and the mean velocity is usually obtained by the aid of Prony's formula.

* For abstract of the results of the above experiments see Appendix

$$\frac{U}{V} = \frac{V + 2\,372}{V + 3\,153}$$

The value of U thus obtained, multiplied by the area of the cross section, gives the discharge

But this formula, deduced as it was by Prony from Du Buat's experiments on small wooden canals, could not evidently apply to all cases, seeing that the resistance which has been proved by M. Darcy and M Bazin's investigations to have an important influence on the value of $\frac{U}{V}$, varies greatly with the nature of the bed It was therefore necessary to study the subject afresh in connection with the other investigations of M Bazin The question was in itself a difficult one, and indeed, although the filament animated with the maximum velocity may, in a small stream, be generally very near the surface, yet when the depth is great, the distance of the point of maximum velocity from the surface increases as the ratio of the depth to the width of the stream is increased The boatmen on the Rhine and our ferrymen have long been aware of the fact, that a deeply laden boat with a great draught, goes down stream more rapidly than merely floating bodies or than the surface water itself It thus follows that floats do not always give the value of the maximum velocity, that is, unless they are immersed to the proper depth On the other hand, when the depth of the stream is very small, the influence of the thickness of the float,—the point of maximum velocity being in that case very near the surface,—renders it difficult to check the results by means of those furnished by the hydrometric tube, which moreover are not exact themselves, unless the tube is sufficiently immersed

These remarks will suffice to explain the difficulty of this problem in experimental hydraulics, which was taken up by M Bazin, and the necessity on his part of selecting, from among the various sets of experiments at his command, those which were least liable to error from the two causes above mentioned, or from others of a less important kind

Having observed, on an examination of the results of the experiments that the ratio $\frac{U}{V}$ diminished in proportion as the resistance of the bed increased, he concluded that there was some relation between the ratios $\frac{V}{U}$ and $\frac{RI}{U^2}$, of the form $\frac{V}{U} = 1 + f\left(\frac{RI}{U^2}\right)$

$\frac{V}{U}$ being evidently unity when $f\left(\frac{RI}{U^2}\right)$ becomes zero

Among the forms which may be taken by the unknown function, the simplest being $f\left(\frac{RI}{U^2}\right) = K\sqrt{\frac{RI}{U^2}}$, in which K is a constant co-efficient, M Bazin sought to determine whether this formula was not really sufficiently in accordance with the results of observation, to allow of a mean value of the co-efficient K being represented by the formula —

$$\frac{V}{U} = 1 + K\sqrt{\frac{RI}{U^2}} \text{ which would give}$$

$$K = \frac{\frac{V}{U} - 1}{\sqrt{\frac{RI}{U^2}}}$$

The examination was confined to the observations which were most free from irregularity The velocities were determined by floats, and were checked by means of the hydrometric tube. M Bazin found that although the value of the co-efficient K was not altogether constant for different values of $\frac{RI}{U^2}$, there was very little difference from the mean K = 14·1, or simply K = 14, so long as $\frac{RI}{U^2}$ did not exceed ·001

In most cases $\frac{RI}{U^2}$ will be under this quantity, and it therefore follows that the ratio of the observed maximum velocity near the surface, to the mean velocity, will be given for the generality of cases occurring in practice, by the formula $\frac{V}{U} = 1 + 14\sqrt{\frac{RI}{U^2}}$, from which we have

$$V - U = 14\sqrt{RI}\,^*$$

This formula shows that the ratio $\frac{V}{U}$ increases proportionally to the square root of the hydraulic mean depth, to the square root of the fall in unity, and inversely to the mean velocity In canals of which the width is very great relatively to the depth, the hydraulic mean depth differs but slightly from the latter, and the ratio $\frac{V}{U}$ then increases proportionally to the square root of the depth

Comparison of the results of the above formula with those obtained by

* See p 295 for the value of the co-efficient of $\sqrt{RI}$ corresponding to values of U, V, and R in feet

Prony's formula, and by experiment —The question under consideration being of great importance, since the measurement of the surface velocity by means of floats is all that in most cases can be effected, it was necessary to compare the results of actual observation with those obtained from the proposed formula and that of Prony This has been carefully done by M Bazin, who has tabulated the observed surface velocities ranging from 0 315 mètres to above 6 0 mètres per second An examination of this list shows that if Prony's formula agrees sufficiently well with observation where the resistance of the bed is inconsiderable, (as might have been expected, since it was deduced from experiments in channels lined with planks,) the agreement ceases in proportion as this resistance is increased As M Bazin remarks, the maximum error arising from the use of the proposed formula, on 18 different experiments in which the value of $\frac{RI}{U^2}$ exceeds 0 001, is on the average within 0 03 of the observed mean velocity, while Prony's formula gives an average error of 0 186 of this velocity, and in some instances is as much as half the observed mean velocity

The result of this examination shows that the ratio between the maximum observed velocity near the surface, by floats or other means and the mean velocity, may be represented, with sufficient accuracy for practical purposes, by the formula

$$V - U = 14 \sqrt{RI}$$

$$\text{or } U = V - 14 \sqrt{RI}$$

To determine the discharge of a stream, we may obtain, by direct observation the values of V, R, and I, and thence the mean velocity U, which, multiplied by the area of the cross section, will give the required quantity, there being no occasion to make allowance for the resistance of the bed, since the influence due to it is included in the values taken by the known quantities

If the above formula be connected with those for the four types of canal previously described, as those which comprise the channels which have most generally to be dealt with in practice, the engineer will have it in his power to solve the various questions which come before him relating to the velocity and discharge of existing channels, or to the formation of new channels under given conditions. The results, if not quite exact, will be a closer approximation to accuracy than he has the means of obtaining from any of the older formulæ

Following Prony's example, M Bazin has appended to his Report, various tables for facilitating calculations relating to the uniform motion of water in channels

The formulæ he has obtained being

$$\frac{\mathrm{RI}}{\mathrm{U}^2} = \alpha + \frac{\beta}{\mathrm{R}}, \text{ we have}$$

$$\mathrm{U} = \frac{\sqrt{\mathrm{RI}}}{\sqrt{\alpha + \frac{\beta}{\mathrm{R}}}}$$

$$\text{also } \mathrm{U} = \mathrm{V} - 14 \sqrt{\mathrm{RI}}$$

$$\text{hence } \frac{\mathrm{U}}{\mathrm{V}} = \frac{1}{1 + 14\sqrt{\alpha + \frac{\beta}{\mathrm{R}}}}$$

He has carried out his calculations for the four types of channel above-mentioned, under which he proposes to classify practical cases, to the following extent

1 Two tables giving, for the various values of the hydraulic mean depth R which are likely to occur in practice, the corresponding values of $\alpha + \frac{\beta}{\mathrm{R}}$ and of $\sqrt{\alpha + \frac{\beta}{\mathrm{R}}}$.

2 Two tables showing the ratio $\frac{\mathrm{U}}{\mathrm{V}}$ of the mean to the maximum velocity, for different values of R, or of the co-efficient $\alpha + \frac{\beta}{\mathrm{R}}$

These tables may prove useful, but the formulæ themselves are so simple and so convenient for practice, that engineers hardly require their aid

Investigation of the resistance of the air at the surface of a stream — It has been generally supposed that this resistance is considerable, and that it should be taken into account M Darcy accordingly entered upon a consideration of this question also, in connection with the distribution of the velocity throughout either a longitudinal or transverse section For this purpose, he had a rectangular tube 0·80 mètre wide by 0 60 mètre deep, prepared in 1857, and at a later date, (1859,) M. Bazin constructed from it a second, 0·48 mètre by 0 30 mètre The discharge of these tubes running full under a given fall was noted in the first instance, the top was then removed, and the water was again thrown into the open tube Other special experiments having proved that in the discharge of *full* tubes, the velocity of the filaments situated

at the same distance vertically above and below the axis, was equal, it therefore followed that the discharges of the two portions above and below the horizontal line bisecting the section were equal, consequently, if in an open tube of the same width and with the same fall, a stream with half the depth of that of the closed tube, were made to flow, the retarding influence due to the resistance of the air would be exhibited by its rendering the discharge of the open tube less than half that of the closed tube of equal width

Two sets of experiments, which are well adopted to show the comparative results under the above conditions, give the following difference —

Tube, 0 8 metre wide

	Closed	Open
	m	m
Depth,	0 50	0 2158
Fall,	0 00427	0 00430
	m c	m c
Discharge,	0 618	0 307

Tube, 0 48 m wide

	Closed	Open
	m	m
Depth,	0 30	0 1513
Fall,	0 00627	0 006
	m c	m c
Discharge,	0 191	0 093

These experiments which were made during a calm, seem to indicate that the resistance of the air has not much influence in retarding the motion, at least, as regards the quantity discharged

But the case is very different as regards the distribution of the velocities of the different filaments in a cross section Numerous experiments, which M Bazin carefully executed by means of M Darcy's hydrometric tube, by which the velocities were observed at 45 different points, showed, as we have explained above, that the distribution of these velocities in the closed tube was remarkably symmetrical, and that by means of diagrams, showing the position of the points of equal velocities at different distances from the axes of the tube, a series of perfectly symmetrical curves was obtained. The nearer the filaments, or the curves referring to them, approached the sides of the tube, the more nearly the curves approximated to the form of a rectangle with the angles rounded off

M. Bazin, however, obtained quite different results in the case of open tubes The curves of equal velocity nearest the sides are still nearly rectangular, of which the vertical portions terminate nearly at right angles to the surface, but, as the distance from the sides and the velocity, increase, the curves from the opposite sides tend to meet by becoming more and more inflected towards the surface, until at length, when the depth of the stream is equal to, or exceeds one-third the width, the curves nearest the middle, in which the velocity is greatest, become completely closed, and thus define the limits of a kind of central nucleus, possessing throughout a velocity in excess of that at the surface This tendency of the curves to close or to become complete is the more marked as the resistance of the bed increases, and as the velocity is diminished Similar effects are observable in the sections of all the channels, the form only of the curve being influenced by that of the channel.

M Bazin, in determining the curves of equal velocity, has been careful to distinguish the one referring to the filaments animated with the *mean* velocity Its form, however, does not differ in character from the others

How these differences in the distribution of the velocities at different points in the cross section are produced, without apparently influencing the amount of the discharge—as the comparative experiments on closed and open tubes above described appear to prove, is a question which science has as yet failed to explain However it may be, M Bazin, by having taken the pains to determine for a number of regular sections, rectangular and circular, 7, 8, or even 10 curves of equal velocities, has furnished very valuable data to those who may wish to study the law of the distribution of velocities throughout the section of a stream—data which up to this time have been wanting to verify any hypothesis on the subject which may be brought forward

Difference of velocity at different points in the same vertical section — M. Bazin's researches have also been extended to this subject, which has engaged the attention of numerous authors He used for the purpose M. Darcy's hydrometric tube, which furnished the means of obtaining more accurate results and especially results which admitted of comparison one with another,—than could be arrived at by any other method available Unfortunately, however, the channels experimented

on were only from 0 084 mètre to 0 380 mètre deep, and with mean velocities from 2 573 mètres to 0 613 mètres per second consequently, their limits were too restricted to render it possible to arrive by means of them, at the real law of the variation of velocity

M Bazin considers that the observations justify the conclusion that the excess of the surface velocity V over the velocity of a filament at the depth h below the surface of a stream, whose fall I and depth H are given, varies as the square root of the depth h, and that it may be expressed by the following formula—

$$V - v = k \sqrt{RI} \left(\frac{h}{H}\right)^2$$

in which k is a co efficient not differing greatly from 20

From this we obtain

$$v = V - \frac{k}{H^2} \sqrt{RI}\, h^2$$

which shows that the velocity at a given depth h increases as the whole depth is increased, though not by a constant quantity, or that the parameter of the parabola, expressed by $\frac{k}{H^2} \sqrt{RI}$, varies as the depth, instead of remaining constant, as is supposed by an able engineer* who has propounded a theory of the uniform motion of water

The preceding formula does not hold good except when the maximum velocity is very near the surface, which was the case with the experiments which were analysed by M Bazin It differs somewhat from the formula deduced by M Boileau from experiments made on small depths, according to which the geometrical relation between the depth and velocities of the different filaments in the same vertical would also be represented by a curve nearly parabolic in form, of which the summit corresponding to the maximum velocity would be—for the cases observed by that officer—at a distance below the surface of about one-fifth the total depth of the stream

Under these circumstances, considering the facilities which M Darcy's tube gives for observing the velocities at various depths, it would seem desirable that M Bazin, or some other engineer who may have the opportunity, should take observations on a large stream such as

* It is supposed that M Dupuit is here alluded to

† See Messrs Humphrey and Abbot s Report on the Mississippi, for numerous observations of sub surface velocities on that river

the Rhine or Rhone, and extend the investigation to sufficiently wide limits to allow of its being possible to arrive at a knowledge of the law which governs the change of velocity from point to point in the same vertical line Besides the interest which the solution of this question presents in a purely scientific point of view, as it would lead to a knowledge, at all events approximately, of the bottom velocity, it would be extremely useful to engineers

On the variable motion of streams —We know that the conditions of the motion of water in streams of which the regime is not uniform, has been the subject of important researches on the part of M Poncelet and M Bélanger, who have given an analytical expression for the lowering of surface between two sections when the mean velocities differ There enters into this expression a numerical co-efficient of the term containing these velocities and the ordinary co-efficients of the resistance of the sides and bed, which are supposed to be nearly the same as in the case of uniform motion

M Bazin has entered upon a discussion of the results of this formula for the different cases of variable motion which can arise, and has compared them with those obtained by observation. In the case of a sudden change of level (ressaut), the circumstances of the motion are of so confused a character as to render it extremely difficult to obtain sufficiently accurate measurements of the height and form of the back-water (remous)

The distribution of the velocities over any one section and the resistance offered by the bed cannot, moreover, be the same as in the case of uniform motion, and it may, therefore be easily conceived how difficult it is for theory on the one hand and experiment on the other to discern and establish the real laws of such phenomena Nevertheless, this portion of M Bazin's researches, by furnishing fresh results of observations which have been collated with the greatest care, cannot but tend to throw fresh light on this intricate branch of the motion of water in channels.

To recapitulate We have shown by a detailed analysis of M. Bazin's report, that the nature of the bed of a channel exercises an influence on the resistance it opposes to the motion of water which it is not permissible to neglect, after the example of Prony, Eytelwein,

and, indeed, of all writers on hydraulics who have given formulæ on the subject, and that this influence varies so considerably for beds of channels of different kinds, that it is impossible to provide, by any single formula, for all cases which are liable to present themselves in practice

Several mathematicians have of late years attempted, by means of more or less ingenious hypotheses, to solve these intricate questions theoretically, but as the hypotheses are not founded on the actual circumstances of the motion of fluids, the consequences to which they lead are not found to be in accordance with the results of observation—even in the case of uniform motion

The solution of this important question, like that of so many others on Natural Philosophy, has evaded the grasp of mathematical analysis The engineer, who must, however, have rules to guide him in practice, is thus forced to have recourse to observations and to content himself with the empirical formulæ which embody their results No doubt such a mode of solving questions of so important a character is not so striking as solutions which are derived from scientific theory based on considerations more or less ingenious, or what is too frequently the case, on hypotheses which do not conform to actual facts Engineers who, like M Darcy, M Bazin and others, devote themselves to the practical treatment of the subject with a perseverance which extends to the sacrifice of health or even of life, do not, however, the less merit the cordial acknowledgments of all true lovers of science

By carrying forward to completion the operations which were initiated by M Darcy, and by an able and lucid discussion of their results, M Bazin has rendered a great service to the practical engineer Actuated by a feeling of deep regard for the chief who opened the way for him, he has handsomely attributed to him the credit of devising and organizing the investigations, but his own services are nevertheless very considerable, and cannot fail to elicit the approbation of the Academy, and of the distinguished corps to which he has the honor to belong

Your Committee, therefore, propose to accord the approval of the Academy to M Bazin's Memoir, and to order it to be printed in the "Recueil des savants étrangers," also that this report be forwarded to the Ministers for Agriculture, Commerce and Public Works

The conclusions of this report are approved.

APPENDIX.—Table I giving the values of $\frac{U}{\sqrt{RI}}$ corresponding to values of R from 1 to 20 feet

Values of R in feet	Bed and sides, fine plaster — 1st type	Bed and sides, cut stone. — 2nd type	Bed and sides, rubble masonry — 3rd type	Bed and sides, earth. — 4th type
1	141	118	87	48
1.5	143	122	94	56
2	144	124	98	62
2.5	145	126	101	67
3	145	126	104	70
3.5	146	127	105	73
4	146	128	106	76
4.5	146	128	107	78
5	146	128	108	80
5.5	146	129	109	82
6	147	129	110	84
6.5	147	129	110	85
7	147	129	110	86
7.5	147	129	111	87
8	147	130	111	88
8.5	147	130	112	89
9	147	130	112	90
9.5	147	130	112	90
10	147	130	112	91
11	147	130	113	92
12	147	130	113	93
13	147	130	113	94
14	147	130	113	95
15	147	130	114	96
16	147	130	114	97
17	147	130	114	97
18	147	130	114	98
19	147	130	114	98
20	148	131	114	98

1st type, $\frac{RI}{U^2} = .0000045 \left(10.16 + \frac{1}{R}\right)$ Where U = mean velocity in feet per second

2nd „ $\frac{RI}{U^2} = .000013 \left(4.354 + \frac{1}{R}\right)$ R = hydraulic mean depth in feet.

3rd „ $\frac{RI}{U^2} = .00006 \left(1.219 + \frac{1}{R}\right)$ I = inclination or fall in unity

4th „ $\frac{RI}{U^2} = .00035 \left(.2438 + \frac{1}{R}\right)$

Example.—Given, hydraulic mean depth, R, = 4 feet, fall, I, = $\frac{1}{10,0}$ or 6.3 inches per mile

To find the mean velocity, U, in channels lined with different kinds of material.

feet per second

For a channel lined with brickwork, fine plastered, $U = 146\sqrt{\frac{4}{10,000}} = 2\ 92$

Do,	cut-stone wall,	$U = 128 \times \frac{1}{50} = 2\ 56$
Do,	rubble masonry,	$U = 106 \times \frac{1}{50} = 2\ 12$
Do,	earth,	$U = 76 \times \frac{1}{50} = 1\ 52$

TABLE II — Giving the values of the ratio $\frac{U}{V}$ of the mean and maximum velocities corresponding to different values of the hydraulic mean depth, from 1 to 20 feet

Values of $\frac{U}{V}$ —

	Bed and sides, fine plastered	Bed and sides, cut stone	Bed and sides, rubble masonry	Bed and sides, earth
1	85	82	77	65
2	85	83	79	71
3	85	83	80	73
4	85	83	81	75
5	85	83	81	76
6	85	84	81	77
7	85	84	81	78
8	85	84	81	78
9	85	84	82	78
10	85	84	82	78
11	85	84	82	78
12	85	84	82	79
13	85	84	82	79
14	85	84	82	79
15	85	84	82	79
16	85	84	82	79
17	85	84	82	79
18	85	84	82	79
19	85	84	82	79
20	85	84	82	80

The values in the above table are thus obtained—

$V - U = 14\ \sqrt{RI}$ (see p 287) in French measurements

$= 25\ 3\ \sqrt{RI}$ approximately, in English do.

$U = m\ \sqrt{RI}$ m being the co-efficient given in the preceding table for different values of R

$$\text{hence } \frac{U}{V-U} = \frac{m}{25\ 3}, \text{ and } \frac{U}{V} = \frac{m}{m + 25\ 3}$$

The following is a list of the experiments from which the co-efficients $\frac{U}{\sqrt{RI}}$ for earthen channels are derived

No of Experiment	Fall in units I	Hydraulic mean depth (R) in feet	$\frac{U}{\sqrt{RI}}$ Observed	$\frac{U}{\sqrt{RI}}$ Calculated
		Chazilly Channel —Series No 37		
1	.000792	0.957	41.7	47.1
2	.000808	1.201	53.4	51.6
3	.000858	1.407	52.1	54.7
4	.000842	1.558	55.0	56.9
		Series No 38		
1	.000957	0.957	41.1	47.1
2	.000929	1.181	51.4	57.2
3	.000993	1.404	48.2	51.7
4	.000986	1.539	50.2	56.5
		Series, No 41		
1	.000415	1.013	44.5	48.7
2	.000450	1.381	50.9	54.3
3	.000455	1.568	52.5	56.9
4	.000441	1.712	54.9	58.7
		Grosbois Channel—Series No 47		
1	.000464	1.089	36.6	49.6
2	.000450	1.378	53.2	51.3
3	.000479	1.627	51.4	56.3
4	.000493	1.712	57.9	58.7
		Series No 48		
1	.000555	.987	41.1	47.6
2	.000555	1.296	55.0	53.0
3	.000525	1.561	55.0	56.9
4	.000515	1.712	58.8	58.7
		Series No 49		
1	.000250	0.961	57.0	47.1
2	.000275	1.315	70.1	53.4
3	.000246	1.565	69.4	56.9
4	.000275	1.781	66.1	59.6
		Series No 50		
1	.000310	1.050	45.0	48.9
2	.000290	1.417	62.1	54.9
3	.000330	1.647	55.6	51.7
4	.000330	1.847	57.0	60.3
		Marseilles Canal		
7	.00043	2.871	72.1	69.5

No of Experiment	Hydraulic mean depth (R) in feet	$\frac{U}{\sqrt{R\,I}}$ Observed	$\frac{U}{\sqrt{R\,I}}$ Calculated	
		Du Buat's Experiments on the Canal Du Jard		
3	1 680	57 6	58 3	The bed of the Canal was covered with a growth of reeds for Experiments No 14 and 28, which explains the low rate of the observed velocity
4	1 909	57 0	64 8	
7	2 050	62 6	62 5	
20	2 582	82 6	67 2	
14	2 887	42 9	69 5	
23	3 589	51 8	73 9	
		Du Buat's Experiments on the River Hayne		
17	4 829	74 6	79 5	Experiment No 40 is less certain than the others, owing to its having been made during a high wind
46	4 915	84 0	80 0	
10	5 738	69 0	82 6	
22	5 827	85 7	82 9	
		Experiments by Funk on the Weser		
36	2 247	79 7	64 5	
49	4 497	71 3	78 2	
69	5 233	101 6	81 1	
57	5 331	77 7	81 3	
68	6 142	88 0	83 8	
74	6 670	90 5	85 1	
71	6 759	81 1	85 3	
48	7 223	89 3	86 4	
76	7 421	88 5	86 8	
79	7 595	93 3	87 2	
66	8 077	96 5	88 1	
80	8 148	93 3	88 1	
81	8 612	93 1	89 1	
51	8 694	74 1	89 3	
82	8 930	89 8	89 6	
83	9 308	91 3	90 2	
58	9 436	83 8	90 4	
85	9 718	91 3	90 7	
63	9 984	87 8	91 1	
72	10 207	92 2	91 3	
86	10 236	95 1	91 4	
84	10 456	90 7	91 6	
65	10 525	92 7	91 8	
87	10 689	94 0	92 0	
70	11 194	93 4	92 5	
88	11 286	92 2	92 7	
89	11 700	93 8	93 0	
73	12 077	95 4	93 4	
75	12 474	94 5	91 0	
77	12 671	97 1	94 0	
91	12 904	94 0	94 3	
64	13 278	92 2	94 7	
90	13 350	92 2	94 7	
78	14 134	95 8	95 2	

No of Experiment	Hydraulic mean depth (R) in feet	$\frac{U}{\sqrt{RI}}$ Observed	$\frac{U}{\sqrt{RI}}$ Calculated
		Experiments by Brunings on the branches of the Rhine	
34	4.121	87.5	76.6
59	6.841	121.9	85.7
43	7.267	91.3	86.6
47	7.710	88.0	87.5
53	8.658	84.4	89.1
50	9.16	92.2	90.0
56	9.367	92.2	90.2
52	9.843	99.4	90.9
45	10.263	85.8	91.4
60	11.673	110.8	93.1
55	12.142	102.3	93.4
44	12.444	81.3	94.0
67	12.484	92.4	94.0
62	16.273	92.2	96.7
54	16.742	92.4	96.9
61	16.998	92.4	97.1
		Experiments by Bonati on the Po	
95	8.661	98.0	89.1
96	12.260	88.2	93.6
97	23.229	86.6	99.8
		Experiments by the Roman School of the Ponts et Chaussées on the Po and Tiber	
99	9.357	104.5	90.4
98	13.309	96.3	96.2
		EXPERIMENTS ON THE SEINE	
		1st Series, executed at Paris in 1851 and 1852	
1	5.663	78.1	82.6
2	7.083	73.7	86.2
3	8.428	71.7	88.7
4	9.475	92.5	90.4
5	10.919	95.6	92.4
6	12.185	92.4	93.7
7	14.498	94.0	95.6
8	15.020	98.3	96.0
9	15.929	89.5	96.5
10	16.847	102.1	97.1
11	18.386	107.6	98.0

No of experiment	Hydraulic mean depth R in feet	$\frac{U}{\sqrt{RI}}$ Observed	$\frac{U}{\sqrt{RI}}$ Calculated	
	2nd Series, executed at Poissy, Triel, and Meulan in 1852 and 1853			
1	7 100	91 3	86 2	
2	7 677	89 5	87 3	
3	11 240	93 3	92 7	
4	12 428	86 4	93 8	
5	13 570	91 1	94 7	
6	14 200	93 6	95 3	
7	15 863	92 7	96 5	
8	16 844	92 4	97 1	
9	17 864	91 1	97 6	
	Experiments on the Saone, executed in 1858 and 1859			
1	3 878	45 3	75 5	The discrepancies resulting from the first three experiments are probably due to the uniform fall adopted for all the experiments, $\frac{1}{25000}$ being too high for those three
2	4 770	58 8	79 3	
3	7 057	58 6	86 0	
4	8 924	84 8	89 5	
5	10 873	88 9	92 2	
6	11 611	88 6	93 1	
7	11 805	89 3	93 3	
8	13 268	97 8	94 5	
9	14 643	98 0	95 6	
10	15 830	91 5	96 3	

REMARKS BY TRANSLATOR

The results above given do not all possess the same value Bruning's observations on the Rhine were made between 1790 and 1792, with a view to ascertain the distribution of its supply among its principal arms, and did not comprise measurements of the surface fall, which was a matter of secondary importance as regarded the special object of the operations The values given to the surface falls in Funk's Treatise on Hydraulics, and which were reproduced by Eytelwein, were ascertained subsequently, either by theory, so that they should correspond with the received formulæ, or, perhaps, also from a series of levels which were carried out in 1797 Bruning's experiments are, therefore, not of much value for the above comparison There is also reason to doubt the accuracy of the surface falls which are given for Funk's observations on the Weser, as the same fall is allowed for a

group of observations, a thing not likely to be strictly true in a natural stream The experiments on the Po and Tiber are open to similar remarks

The mean velocities for Du Buat's experiments on the Canal du Jard and on the River Hayne, have been re-calculated on the basis of M Bazin's formula, instead of that of Du Buat, which was deduced from observations on small wooden channels, and which, as M Bazin shows, is not suitable for larger streams

After rejecting Bruning's, and several other, experiments which yield very anomalous results, M Bazin has grouped the experiments above enumerated together, and has thus obtained 19 different mean values of $\frac{U}{\sqrt{RI}}$ corresponding to different values of R, these are

Mean of	Value of R in feet	$\frac{U}{\sqrt{RI}}$ Observed	$\frac{U}{\sqrt{RI}}$ Calculated *
5 Experiments on the Chazilly and Grosbois channels,	1 000	47 75	47 93
6 Ditto, ditto,	1 332	56 43	53 60
Idem,	1 562	55 16	56 85
Idem,	1 722	57 97	58 87
4 Experiments by Du Buat on the Canal du Jard,	2 064	63 07	62 63
Experiment by M Baumgarten on the Marseilles canal,	2 871	72 15	69 46
4 Experiments by Du Buat on the river Hayne,	5 328	77 37	81 37
5 Experiments by Funk on the Weser,	5 879	80 82	83 08
Idem,	7 690	90 78	87 42
Idem,	9 200	89 66	90 03
4 Experiments on the Seine,	9 610	89 99	90 62
5 Experiments by Funk on the Weser,	10 282	91 35	91 52
4 Experiments on the Saone,	10 804	87 85	92 15
5 Experiments by Funk on the Weser,	11 388	93 77	92 82
4 Experiments on the Seine,	11 768	93 50	93 21
6 Experiments by Funk on the Weser,	13 133	94 28	94 49
3 Experiments on the Saone,	14 567	96 67	95 62
5 Experiments on the Seine,	15 669	92 01	96 37
4 Experiments on the Seine,	16 541	98 81	96 9

* By formula $\frac{RI}{U^2} = 00035 \left(24384 + \frac{1}{R} \right)$

The accuracy of the formula may be further tested by applying it to various observations recorded in Messrs. Humphrey and Abbot's Report on the Mississippi

1 Observations by Krayenhoff on the rivers in Holland, made in 1812 (pages 307 and 316, Mississippi Report)

Names of rivers	Hydraulic mean depth	Observed surface fall	Mean velocity Observed	Mean velocity by Bazin's formula
1 Rhine at Byland,	16 6 feet,	$\frac{1}{9038}$	3 57	4 15 *f*
2 Rhine at Paunerden,	11 2 ,,	$\frac{1}{9038}$	3 28	3 26
3 Waal at upper mouth,	11 1 ,,	$\frac{1}{8750}$	3 16	3 31
4 Rhine below the Yssel,	7 6 ,,	$\frac{1}{7950}$	2 92	2 69
5 Yssel at mouth,	6 0 ,,	$\frac{1}{8650}$	2 77	2 19

2. Observations on the Neva by Destrem (pages 308 and 316)

1 Neva,	35 4 ,,	$\frac{1}{37500}$	3 23	3 14
2 Great Nevka,	17 4 ,,	$\frac{1}{49000}$	2 04	1 88

3 Observations on the Mississippi (pages 315 and 316)

1. Above Vicksburg,	64 5 ,,	$\frac{2\ 65}{43525}$	6 82	6 56
2 Ditto,	52 1 ,,	$\frac{1\ 88}{43525}$	5 56	4 89
3 Columbus,	65 9 ,,	$\frac{1}{14700}$	6 96	7 03

It should be remarked that the surface falls for the above three sets of observations are the observed falls, and that no deduction has been made for the loss of head arising through bends Messrs Humphrey and Abbot have taken this loss into account in their calculations for the mean velocity; but, as M Bazin has derived his formula* from observations, many of which were made in streams in which various curves and irregularities existed, its accuracy can only be fairly tested by application to data of a similar character. If a deduction were to be made from the observed surface fall on account of bends, higher co-efficients than are allowed in the formula would appear to be neces-

sary, as will be seen from the following observations on the Mississippi at Vicksburg, which were made with the greatest possible accuracy

	I		II
Discharge,	1,225,000 cubic feet per second,	.	750,000 cubic feet per second
Mean velocity,	6 82 feet per second,		5 56 feet per second
Hydraulic mean depth, 64 5 feet,			52 1 feet
Fall in straight portion of channel,	$\frac{490}{11225}$		$\frac{310}{11225}$
Co-efficient $\frac{U}{\sqrt{RI}}$	128	.	140
Co efficient by M Bazin's formula, 104 7		..	104 2

This would seem to indicate that the formula would give too low results if applied to observations on large straight canals It must also be acknowledged that the formulæ of Du Buat and Prony give as accurate results in some cases, as the new formula It is evident that further observations are required on large canals before M Bazin's conclusions can be received with implicit confidence, and it is to be hoped, that the series of experiments which were to have been executed on the Ganges Canal, under the direction of the late lamented Lieut - Colonel Dyas, R.E, will not be allowed to drop

J C A.

No CXCVIII

TRELLIS WORK IN CHUNAM

By Lieut S S Jacob, *Executive Engineer, Jeypore*

The place where trellis work is to be made, is first built up with a thin wall of rubble masonry or brick and lime This is to serve as a temporary backing and is afterwards removed.

The lime (from blue limestone) is then slaked and allowed to remain so for about half an hour, when it is passed through a sieve, so as to be freed from all lumps, one-third of fine soorkee is then added to it and the whole is well mixed, care being taken not to add too much water

A clear even space is then prepared on the ground, and the mortar is spread over it in a layer of 2 inches or 3 inches in thickness, and, as soon as it has become consistent enough to bear the impression of the finger, it is divided by the trowel into bricks of about 6 inches × 4 inches, a larger size than this would probably cause fracture of the brick.

A wall of these bricks is then built up in front of the temporary backing above mentioned, and a small quantity of the finest mortar (composed of 1 part lime and 4 parts soorkee) is used to cement them, and the wall surface is carefully levelled by means of floats and straight edges It is allowed about a day to dry

The next day, the pattern required is drawn on it by the aid of compasses, or string powdered with charcoal If an elaborate pattern is required, it is first drawn on paper and then pricked through The paper is placed on the surface of the wall, and charcoal being powdered over it, leaves the required pattern on the wall.

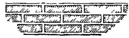
The hollow spaces are then neatly cut out with fine pointed trowels and chisels, water being gently sprinkled on the work as it proceeds, to keep the place moist

The pattern is cut right through to the backing which is removed in 2 or 3 days, as soon as the trellis is sufficiently dry to stand by itself It may be made any color that is wished

If it should be required to be polished, this may be done by applying a thin coat of pure lime and powdered marble well mixed and sifted, and after a day or so, polished with the same instruments used before When it is properly polished, it presents the appearance of pure marble, and will last for many years

Many specimens of this trellis work may be found in native cities, some of the designs are remarkably pretty In the accompanying *Plate*, are patterns taken from some of the windows in Jeypore, which will serve to illustrate the subject

They can be used in many situations, as panels to ornamental walls, balustrades, railings, band-stands, windows, doors, partition screen walls, when the pattern would be similar to venetian blinds, the length of each aperture being about 3 or 4 inches, for clerestory windows, ventilators, &c, &c.



I have used them in the circular space above the door frames of common doors for servants quarters, a common radiating pattern, as the rays of the rising sun, which presents a good effect, and affords ventilation, and I think this description of work would be found useful in many of our buildings

S. S. J

No CXCIX

PENDULUM AND STANDARD BAR OPERATIONS OF THE G T. SURVEY IN 1866-67.

(2nd Part)

Abstracted from the Annual Report of LIEUT -COLONEL J. T WALKER, R E, F.R S, *Superintendent, G T Survey*

In my Report for last year, I stated that Captain Basevi had commenced the operations for determining the force of gravity at certain of the stations of the Great Indian Arc, which had been suggested by General Sabine, the President of the Royal Society * For this purpose he had been supplied with two pendulums and other instruments, the property of the Royal Society, which had already been employed in similar investigations in other parts of the globe, and with which a complete series of observations had been made at the Kew Observatory shortly before the instruments were despatched to India, to facilitate the eventual combination of the results of the operations in this country with all previous or future operations of a like nature.

I may here repeat that a fact of great scientific importance was elicited from the results of the work of last year, that the density of the strata of the earth's crust under, and in the vicinity of, the Himalayan mountains is less than that under the plains to the south, the deficiency increasing as the stations of observation approach the Himalayas, and being a maximum when they are situated on the range itself. The stations at which observations were taken during the present year are far remote from the influence of the Sub-Himalayan strata, and the results obtained at them are now only very slightly in defect of the theoretical values of the force of gravity, they thus tend to confirm the

* *See* Nos. CXXXVII. and CXLVII. of these Papers

evidence of the first year's operations as to the deficiency of matter in the Sub-Himalayan strata

With a view to imparting the utmost accuracy and precision to the determination of the number of vibrations made by each pendulum at the several stations of the Indian Survey, the President and Council of the Royal Society recommended that the observations should be made in a vacuum the necessary apparatus for this purpose was constructed in London, and sent out with the pendulums Numerous difficulties were at first met with in the management of the vacuum apparatus, the receiver is necessarily of considerable magnitude, to admit of the vibrations of a pendulum of a length of 5 feet, and the powers of the air-pump were found inadequate to the labor of repeatedly exhausting so large a body of air, moreover, the receiver was liable to occasional leakage. All these difficulties, however, have been satisfactorily surmounted, and the apparatus is now in such good working order that the pressure can be reduced below 2 inches, and retained at an average of about 3 inches, throughout a set of observations lasting eight or nine hours

But, in experimental investigations of this nature, it is often found that improvements which are introduced in order to remove known sources of error or uncertainty, bring to light others which had not previously been suspected This has now happened in Captain Basevi's operations, the vacuum apparatus, which was supplied to enable the vibrations to be measured under so slight a pressure that the effects of any uncertainty in the determination of the co efficient of pressure might be reduced to a minimum, has admirably answered the purpose for which it was intended, and has further improved the quality of the observations by protecting the pendulums from the action of currents of air, and from the incidence of dust which often pervades the atmosphere in great quantities, the observations appear to be much more delicate and precise when a pendulum is swung inside the vacuum apparatus, than when it is swung in the air, the correction for pressure is reduced to a minimum, and the variations of temperature are slower, more uniform, and can be measured with greater accuracy But, on the other hand, the correction for temperature is uncertain, and causes much embarrassment, its significance in the reduction of observations of a wide range of temperature is considerable, for a variation of 1° Fahrenheit alters the number of vibrations in twenty-four hours by nearly half a vibration

Before proceeding to describe the steps which have been taken to determine this correction, I may observe that the temperatures are measured by a pair of thermometers inserted in a bar of the same dimensions as the pendulums, and of similar metal, the bar is fixed inside the receiver, and is consequently within a few inches of the pendulum under vibration The calibration errors of the thermometers have been very carefully determined by comparison with a standard calibrated thermometer, and the index errors of the freezing points are ascertained in the usual manner from time to time A further correction is, however, necessary, when the observations are made in a vacuum, for the exhaustion of the air reduces the pressure on the bulbs of the thermometers, and causes the column of mercury to fall, as may be seen by placing a thermometer enclosed in an air-tight tube by the side of an unenclosed thermometer, and comparing the indications of both as the pressure is diminished On the other hand, the friction of the particles of air against each other, and against the sides of the receiver, causes heat to be generated both in exhausting and re-admitting the air, the increase of temperature is not shown so readily by the enclosed as by the unenclosed thermometers, consequently, the effects of the pressure on the bulb of the latter cannot be ascertained until a sufficient period of time has elapsed for both thermometers to be equally affected by the temperature of the air inside the receiver If, meanwhile, the temperature of the observatory is changing, additional complications are introduced However, by patient observation and careful arrangements, the effects of pressure on the bulbs of the thermometers have now been accurately determined, and found to be about two-tenths of a degree for 27 inches of pressure, varying of course with different thermometers

The actual temperatures being ascertained, the next point is to determine the precise effect of a given variation in temperature on the number of vibrations in twenty-four hours. Hitherto it has been supposed that a knowledge of the co-efficient of expansion of the metal, of which the pendulum is constructed, would suffice to enable this effect to be computed by the ordinary theoretical formula, and this supposition has been supported by the evidence of certain experiments which were made by General Sabine in 1824 with one of the pendulums now in India General Sabine observed the number of vibrations which the pendulum

made at a station in London at the temperatures of 47° and 84°, and found that they gave a factor of expansion which coincides with the known factors of similar metals, as determined from direct measurement But his investigations had been restricted to one of the two pendulums, the other had never been tested, and it was therefore necessary for Captain Basevi to ascertain its expansion While so doing, it was decided to extend the investigations to General Sabine's pendulum, because a period of nearly half a century had elapsed since its expansion had been determined, and because it seemed desirable that as all the Indian observations are made in a vacuum, the observations for determining their temperature corrections should also be made in a vacuum

Consequently, Captain Basevi observed a complete series of vibrations at Kaliana, the northern station of Colonel Everest's Arc, in December 1865, under a temperature of 58°, and again in June 1866, under a temperature of 89°, the pressure being about three and a-half inches in both cases The resulting expansions of both pendulums were very consistent, but they were more than a tenth larger than that previously deduced by General Sabine for his pendulum, and indeed were larger than any previously deduced expansions of similar metals It was therefore necessary to re-determine them by independent processes of investigation

In the first instance, experiments were made by vibrating the pendulums in the Observatory at Mussoorie, 6,700 feet above the sea, under the natural pressure of the air, 23 5 inches, at the temperatures of 55° and 84° Twelve sets of observations were made with each pendulum at each temperature, six with the face, and six with the back, of the pendulum turned towards the observer Each set lasted nearly three hours, the three first, the three last, and two intermediate coincidences being observed.

The expansions were then determined by direct micrometrical measurement at the Survey Office in Dehra Doon, 2,300 feet above the sea For this purpose, two frames were constructed, each capable of carrying a pendulum when freely suspended in a vertical position, they were lined from top to bottom, on three sides, with metal cases, which were intended to contain hot water, for the purpose of raising the temperature of the pendulum to any desired point, they were further adapted to move on rollers in a tramway leading to the micrometer microscopes,

which were firmly attached, one above the other, to a large pyramidal block of stone resting on an isolated masonry pillar. The distance between the microscopes being 45 5 inches, fine marks were made at the same distance apart, near the shoulder, and on the tail-piece, of each pendulum The greatest care was taken to prevent the pendulums from being injured by the removal of any portion of the metal, thermometers were attached to them temporarily by springs, the bulbs being plunged into oil cups made of wax and resin, which could be easily made to adhere temporarily to the surfaces of the pendulums, and might be removed at pleasure

The pendulums were first compared together, when at the natural temperature of the experimenting-room, then one of them was removed (in its frame) into an adjoining room, and heated by causing a stream of of hot water to flow continuously through the metal cases, until the pendulum had acquired the desired temperature, it was then brought back (in its frame, with the metal cases full of hot water) into the experimenting-room and again compared with the other pendulum which had remained at the temperature of the room After a sufficient number of comparisons had been made to deduce the relative lengths of the heated and unheated pendulums, the former was allowed to cool down to the natural temperature of the experimenting-room, and the latter was heated, and then both were again compared, twenty comparisons were thus made between the pendulums when both were cold, twenty-six when one was hot and the other cold, and as many more when the temperatures were reversed. The resulting equations of condition were reduced by the method of minimum squares

The factors of expansion which have been deduced at Kaliana, Mussoorie and Dehra are as follows, for each pendulum, No 4 being that employed by General Sabine, with which he obtained a mean factor of 000,010,01 by two sets of experiments, under an atmospheric pressure of 29 8 inches, in London, in the year 1824 —

Pendulum No 4.

Station.	Pressure in inches	Factor of expansion.	Probable error	
Kaliana, .	3 8	·000,011,27	± 000,000,05	By vibrations
Mussoorie, ...	23 5	·000,009,79	± 000,000,08	
Dehra, ...	27 7	000,009,84	± 000,000,13	By direct measurement

Pendulum No 1821.

Kalliana, .	3 2	000,010,93 ± 000,000,05	By vibrations
Mussoorie, .	23 5	300,010,26 ± 000,000,08	By vibrations
Dehra, ...	27 7	000,009,61 ± 000,000,12	By direct measurement

Mean of both Pendulums

Kalliana, .	3 5	000,011,10	By vibrations
Mussoorie,	23 5	·000,010,01	By vibrations
Dehra,	27 7	000,009,73	By direct measurement

The above results indicate a greater degree of expansion at low, than at high, pressures, there are inconsistencies between the determinations at Mussoorie and at Dehra, under a difference of only 4 2 inches of pressure, but these inconsistencies are probably due to the circumstance that a pendulum is necessarily, from its shape, ill-adapted to investigations of this nature, in these pendulums, the "bob" alone contains about thirty-four cubic inches of metal, while the mass of the remainder is only thirteen cubic inches, consequently it is improbable that the metal will be of an uniform temperature throughout, for the variations of temperature must be slower in and near the bob than in any other part of the pendulum, the thermometers are however so placed as to take account of this as far as possible

Still, making every allowance for errors in the above results, it is impossible to escape the conclusion that expansions determined by the vibrations of pendulums, under a very low pressure, are materially greater than those obtained by vibrations in the air, or by direct measurement. Whether this is due to an actual increase of expansion for a decrease of pressure, or to the action of other phenomena which are at present unknown or only imperfectly known, is a problem for future solution

Captain Basevi was necessarily much delayed by having to undertake the above investigations, which were protracted into the middle of the late field season Nevertheless, he was able to take complete sets of observations in the usual manner at three stations of the Great Arc Pahargurh, lat 24° 56′, Kalianpur, lat. 24° 7′, and Ehmudpur lat. 23° 36′, he hopes in the ensuing field season to carry his operations down to Bangalore, lat 13°

During the present year, he has commenced a series of *Magnetic*

observations, which will be carried on in future simultaneously with the pendulum operations. He employs one of the two sets of magnetic instruments, consisting of a unifilar magnetometer and declinometer, and a dip circle, which were constructed for the use of the Indian Survey, under the superintendence of General Sabine and Mr Balfour Stewart, and tested at the Kew Observatory The other set has been used at head-quarers, by myself at Mussoorie, and by Mr. W H Cole, M A, at Dohra, whenever leisure permitted

The results of the observations which have been made hitherto are as follows —

BY CAPTAIN BASEVI

Station		Month of observation	Dip and number of determinations			Declination and number of determinations		Total force in British units, and number of determinations	
			°	′		° ′			
Mussoorie,	.	October 1866	41	41·5	2				
Dehra Doon,		Dec 66, Jan 67	41	27·6	4	2 54·2 E	4	9·7229	7
Meerut,		January 1867	39	7·2	2	2 45·6 E	3	9·5473	3
Agra,		February „	36	1·4	2	2 46·2 E	3	9·3449	4
Paharigurh,	..	March „	31	59·3	4	2 10·0 E	5	9·0914	6
Kahanpur,		April „	30	17·8	2	1 49·0 E	2	9·0873	4
Ehmudpur,		April „	29	53·8	2	2 6·2 E	2	8·9531	4
AT HEAD-QUARTERS									
Mussoorie,	..	May 1867	41	39·9	4	2 37·3 E	2	9·7526	4
Dehra Doon,	..	June „	41	30·2	3	.	..	9·7356	3
„	.	July „	41	31·2	1	..	.	..	..
„	..	August „	41	26·1	3	..		9·7244	2
„	.	Sept „	41	29·5	2		..	9·7203	1

Mr. Hennessey, the head of the Computing Office, and his assistants, have been fully employed, not only in current duties appertaining to the reduction of the triangulation, but in a variety of matters connected with the general operations of the Department, among the chief of which I may mention the verification of the old Standards of Length of the In-

dian Survey This verification had become necessary for the following reasons —The principal standards are two simple bars of iron, ten feet in length, known as standards **A** and **B**, which were sent out to India for Colonel Everest in 1832, with six compensated bars of iron and brass, also of a length of ten feet, intended for measuring base-lines Standard **A** had been employed with the compensation bars at eight base-lines in different parts of India, and had travelled over a distance of many thousand miles Standard **B** was sent back to Europe, to be lodged in the Royal Observatory at Greenwich At each successive base-line it was found that the relative lengths of standard **A** and the compensation bars were altering, the difference increasing year by year, there were also variations in the lengths of the compensated bars *inter se*, but these were comparatively small, had there been only one or two compensated bars which exhibited this discordance with the standard, no doubt could have been felt as to their having altered, and not the standard, for they are necessarily by construction more liable to vary in length than a simple bar of metal, but as there were six compensated bars, and all told the same tale, it seemed possible that their lengths had remained nearly constant, while that of the standard had changed

The differences between standard **A** and the general mean of the six compensated bars are shown in the following table —

Base Lines	Year of measurement	Excess of mean of six compensated bars over standard, in millionths of a yard	Increment on value at Calcutta base line, in millionths of a yard
Calcutta, ...	1832	112 19	.
Dehra Doon, ...	1835	132 59	20 40
Sironj, ...	1838	144 30	32 11
Biddei, ...	1842	183 57	71 38
Sonakoda, .. .	1848	178 65	66 46
Chuch, ...	1854	183 38	71 19
Kurrachee, .. .	1855	195 86	83 67
Vizagapatam, .. .	1863	209 93	97 74

It is evident that any alteration in the length of the standard would necessitate the application of corresponding corrections to the

lengths of all the base-lines, and the sides of the triangles dependent thereon, and that the results of the Indian geodetical operations could not be combined with those of similar operations in other parts of the world until these corrections had been determined and applied

Consequently, two new standards, each ten feet in length, one of steel, the other of bronze, were constructed for the Indian Survey under my superintendence, when I visited England in 1864 Fortunately, Captain Clarke, of the Ordnance Survey of Great Britain, was engaged at that time in making an elaborate series of comparisons between the several standards of length of England, France, Belgium, Prussia, Russia, India and Australia, and he obligingly undertook to compare the new standards with standard **B**, and with the English standards, he also determined the factors of expansion of the new bars, and the errors of the new standard thermometers, which were required to complete the apparatus I have every reason to be much indebted to Captain Clarke, for his able and laborious investigations, they have been published at length, by order of the Secretary of State for War, in a volume entitled "Comparisons of the Standards of Length of England, France, &c."

The new standards arrived at Dehra in 1866 As soon as practicable they were compared, together, and with standard **A**. It was ascertained that their relative length had not been sensibly affected by the journey to India and change of climate, for the measures at Southampton and at Dehra differ by only 06 of the millionth of a yard, a smaller quantity than the probable errors of the determinations. The comparisons with standard **A** show that the relative length of **A** and **B** is at present almost identical with what it was in 1834, when **B** was determined by Colonel Everest, to be 1 28 millionths longer then **A**, whereas its excess is now 3·08 millionths Captain Clarke has shown that the existing relation of **B** to the standard ten-foot bar of the Ordnance Survey differs by less than one millionth from the relation in 1831, and "agrees all but precisely with the mean of the results of the comparisons between these bars in 1831 and 1846"

Thus it may be considered certain that the lengths of both the old Indian standards have not altered appreciably, and that the increment of nearly 100 millionths of a yard in the mean of the six compensated bars on standard **A**, which occurred between the years 1832 and 1863, must have been solely due to changes in the compensated bars.

The length of the standard six-inch scale of this Survey, which determines the values of the compensated microscopes employed in the base-line measurements, has hitherto been assumed to be exactly one-twentieth part of the length of standard **A**. The precise relation of these two standards has been recently determined, and found to agree so closely with the assumed value, that the requisite corrections to the measured base-lines will not exceed half an inch in seven miles.

LOCAL ROADS

THE traveller who, after completing a portion of his journey at the rate of 30 miles an hour on the railway, is, on getting out of the train, obliged to proceed by doolie dâk for the rest of the way at a speed of 3 miles an hour, may be excused if he thinks that the money spent on the few miles of railway would have been more judiciously spent in making ten times the number of miles of metalled road, on which he could at least have proceeded at a reasonable speed throughout Doubtless, he would be wrong in his opinion, for many reasons, but the contrast is at least sufficiently striking to excuse it, and, as a matter of fact, perhaps the want of Local Roads is about the greatest of all wants all over India

Only those who travel much about the country fully appreciate this What lines of road there are, connect the European stations, and we find little difficulty in getting from one to the other, especially as no one travels more than he can possibly help, and then only in the cold or dry season. Natives are accustomed to the want and so do not miss them. But let an Englishman, fresh from England, and accustomed to see every fifth-rate town, or rather village, connected with its neighbours by good macadamized roads, stir off our great military lines of communication and try to find his way through the heart of the district, especially if he makes his eccentric journey in the rains, and he will be struck with unmitigated astonishment

Large villages—nay even good sized towns—he will find everywhere absolutely unconnected with each other, save by a circuitous track, worn into deep ruts and impassable for any vehicle more civilized than a hackery or bylee. Even important and populous towns will be joined only by what are facetiously termed District Roads which in nine cases out of ten mean tracks similar to the

above, only rather straighter and wider. Unmetalled and unbridged, they are absolutely impassable in the rains, and, as a practical fact, the whole population gives up travelling at that season. Let us only try to conceive such a state of things in England, supposing for instance, as indeed was the case 150 years ago, that travelling was next to impossible during the winter months.

That the Government is alive to the above state of things, has been shown by the liberal expenditure lately sanctioned on railway feeders; but this, though an important measure, is but a very partial remedy. It is in the vast districts remote altogether from railways that the evil is still more strongly felt.

A memorandum by Mr. Leonard, late Officiating Chief Engineer of Bengal, has taken up the subject in a systematic way for that great province, and has endeavored to devise a remedy which shall gradually, but surely, effect an improvement. It is already accepted, as a fact, that the cost of local roads cannot be defrayed from Imperial Funds, but must be met by local taxation; and the only question is, how such taxation can best be levied? Mr. Leonard proposes that it should fall on the land, but his arguments on this head do not appear at all conclusive—and we think many will dissent from them.

The lightest and most equitable kind of taxation is obviously that where there is an immediate connexion between the tax paid and the purpose for which it is levied; in other words, that, as far as possible, those should pay the tax, or the greater portion of it at least, who more immediately reap the benefits of it. Now the classes who benefit by the opening of a road are—1st, Travellers and Carriers; 2nd, Consumers; 3rd, and lastly, Producers. But the operation of a land-tax would be virtually to make those who benefit least, pay for the other two.

One great advantage always claimed for a railway over a common road is, that the traffic on the former is directly remunerative, and pays, or ought to pay, a fair percentage on the original cost. But there seems no just reason why roads should not enjoy the same advantage, *i. e.*, that those using them should pay for them. It is

true that, in the case of a railway, the proprietors provide the carriages, while on a road the traveller finds or pays for his own, but it is obvious that this is a distinction rather than a difference

As in a former number of these Papers, therefore, we would again urge a fair trial of the toll-system, which was, we are convinced, condemned or rather abandoned, on very insufficient grounds, in the short trial it had a few years ago The grounds on which this system has been abolished in England* do not exist here,—while the levying of dues on goods in transit is perhaps the most ancient form of collecting revenue in the East. Let, however, some discretion be exercised in the choice of sites for toll-bars Do not erect them where the road traverses a flat open plain, so that they can be evaded, or where, at least, their necessity is not obvious to the ignorant traveller Put them invariably at bridges, and people, who have now to pay for crossing a rickety bridge-of-boats, or a dangerous ferry, will assuredly not grumble at having to pay for crossing a substantial Masonry or Iron Bridge

We do not deny that they would be an evil, but so is all taxation, and it seems to us to be the best and most obvious mode of raising money for roads Already a prospectus has been put forward of a local railway, which is to be made by Native Capital. But capital is scarce in India, and a railroad is an expensive thing Let encouragement be given to similar enterprises in regard to Roads, the Government empowering the proprietors to raise tolls sufficient to pay them a fair return for the capital expended We have no proper traffic statistics† to refer to, but we are sure that a reference

* The land-tax in England forms a very small item in the Imperial Revenue, in India, it is about four fifths of the whole

† In Mr Leonard's Memorandum, Annual receipts from Tolls at Ferries are set down at 8½ lakhs of Rupees for Bengal, and those from the Tolls on District Roads at 83,000 Rs, but the cost of maintenance is not given, nor the number of Ferries and length of Roads on which tolls are levied

The P M General, N W P, in his Report of 1850, calculated from actual data furnished by the Government Bullock Train, that every ton of goods carried on a metalled road could afford to pay two annas per mile for haulage Half this amount would give a fair return for the money laid out on any road where the annual traffic exceeded 10,000 tons

to them would show that such tolls would, in numerous cases, pay a very fair return—while every new road made would create fresh traffic, and so increase the probability of new lines paying

The country is to be covered with Irrigation Canals, but of what advantage is it to increase the produce of a country indefinitely, if you do not at the same time increase the facilities of transport? It is in fact a positive evil, for it keeps down prices and induces the whole population to live from hand to mouth It is true, many of these Canals will be Navigable, offering a far cheaper transport than a road, but they will only affect certain portions of the country, and their effects will only add to the value of, and create a greater demand for, roads

Of course, we have not been arguing the question as between Roads and Railways or Tramways In many parts of the country cheap railways may be better—and in many others, where metalling is expensive and the cost of its repair would perhaps alone swallow up all the tolls, it might be advantageous to adopt a stone tramway or two narrow metalled strips, on which ordinary vehicles could ply Whatever kind be adopted, we only advocate the principle on which, it is submitted, the necessary funds could most properly be raised

J. G. M.

No CC

THE SURAT HIGH SCHOOL

Designed by LIEUTENANT C MANT, R E

THE building is designed in the Gothic style, adapted to the requirements of the climate In the centre is a Lecture Hall, 50 feet by 30 feet, and 30 feet in height to the hammer beams of the trusses On either side of the Lecture Hall is a wing, each divided on the ground floor into four class rooms, three of which are 22 feet × 18 feet, the end ones being 24 feet square Over each class-room, next to the Lecture Hall, is an upper floor room, one of which will be a study and retiring room for the Head Master, the other a library and retiring room for the Assistant Masters There is also an extra class-room over the carriage porch 20 feet square

In the main wall of the building, between the extra class-room just mentioned and the Lecture Hall, is a high pointed archway 15 feet span, the arch is supported on detached stone shafts, and, outside of it, at the level of the floor of the room over the porch, an ornamental wooden gallery, supported on richly carved wooden brackets, and with a handsome carved railing, runs across the end of the Lecture Hall This gallery, besides being a decorative feature, serves the double purpose of affording extra accommodation to the audience, (it being intended that the Lecture Hall shall serve as a public room for lectures, &c ,) and providing a gallery of communication with the three upper rooms, the hexagonal towers at the front corners of the Lecture Hall, one on either side of the carriage porch, being occupied by circular staircases, leading up to, and opening on, the gallery

An arcaded veranda runs along the front of each wing, and a simpler one in rear, the roof of which is supported on ornamental wooden posts with carved brackets The Master's room and library also have arcaded

verandas in front, and these, as well as the ground floor front verandas, are crowned with ornamental perforated parapets and stone strings.

The roof will be of corrugated iron of high pitch, with ample ventilation at the ridge, and through louvred dormers. The whole roof will be lined with deal planking, with an air space between it and the corrugated iron, and the trusses will be hammer-beamed, with curved brackets, struts, and braces. The planking and trusses of the smaller rooms will simply be wood oiled, but the planking of the Lecture Hall roof will be stained, and, with the trusses, varnished.

A carved wooden cornice will run round the Lecture Hall at the junction of the roof slopes with the walls, and the plaster in this room will be decorated by stencilling in oil colors.

The fanlights of all the doors and windows will be glazed in geometrical tracery patterns.

The building will be of brickwork, gauged on the face and pointed. Porebunder, or other stone from Kattyawar, will be used for shafts, strings, copings, and hood mouldings, and black bricks will be introduced to alternate with the red ones, in the voussoirs of the arches in the verandas, and over doors and windows, here and there also in bands and patterns throughout the building.

The roof will be finished with wrought-iron finials and cresting, and painted slate color outside.

The architect would have wished to complete the building with a tall, slender, ornamental lantern at the intersection of the roofs over the Lecture Hall. This would have formed a dominant and crowning feature, which, he admits, the design to a certain extent stands in need of. The funds provided, were however insufficient, and he was reluctantly obliged to abandon the idea.

The building is estimated to cost Rs 79,000, and will be built facing the old Surat Castle, and near the Civil Hospital. The design is by Lieut C. Mant, R E, Executive Engineer, Surat and Broach, and the engraving is from a photograph taken from a perspective view of the design, painted in water colors by Captain Hancock, R E. Both design and estimate have received the approval and sanction of the Bombay Government, and the commencement of the construction only awaits a decision in the educational department, as regards the provision of the necessary funds, Rs 35,000 of which have been given by Mr Sorabjie Jamsetjie Jejeebhoy of Bombay.

C. M.

No CCI

THE ABYSSINIAN RAILWAY

To the Editor

Dear Sir,—If you think the actual strength of the Abyssinian Railway on the date of the Fall of Magdala, when it was in full working order, will be of any use in your series of Engineering Papers, you are welcome to the following —

Officers

1 Captain, R E , Field Engineer in charge (Captain Durrant, R E)

1 Lieutenant, R E , Assistant Field Engineer, Second in Command (Lieutenant Pennefather, R E),

4 Assistant Field Engineers (one non-effective)

1 Locomotive Superintendent

1 Storekeeper

1 Medical Officer

The second in command performed the duties of Adjutant, Paymaster, and took charge of all Military working parties *N B*—The arrangement by which the Paymaster was absent from Zoulla was found inconvenient in practice

Of the other assistants, one was employed in constructing the various bridges , when this duty was completed, he proceeded to join the force in front , a second was traffic manager, and in charge of the locomotive camp at the Pioneer Wells , a third was employed in disembarking the stores from the various transports, and conveying them to the store sheds , and the fourth was Quarter-master and in charge of the depôt at Zoulla.

Sappers and Miners.—2 Sergeants, 1 Corporal (Bombay), 2 Sergeants, 1 Corporal, 2 Naicks (Madras).

Of these, one sergeant was employed surveying, one sergeant as superintendent of railway police, one corporal as draughtsman and under-storekeeper, and one corporal as pay clerk; the remainder were employed as overseers and sub-overseers. *N.B.*—It was a mistake employing a military non-commissioned officer as pay clerk, a regular accountant should have been sent. But like all other departments, there was no cessation of work in mid-day, and consequently no convenient time to muster the men for pay; they had to be paid at odd times.

Infantry.—1 Sergeant, 1 Corporal, 9 Privates, 1st 4th K. O. Royals; 3 Corporals, 11 Privates, 45th Regiment. The above were employed as artificers. 11 Privates, 26th Cameronians. 17 Privates, 18th B. N. Infantry. The above were employed as railway police.

European Civil Subordinates.

	4	Engine drivers		6	Guards
(*a*)	2	Acting do.	(*c*)	5	Clerks
(*d*)	5	Platelayers		3	Railway Telegraph Signallers
	6	Fitters			
	3	Boiler makers		2	Engine drivers, } En-route from Bombay—not joined
(*b*)	3	Stationmasters		3	Firemen, }
(*e*)	3	Firemen		2	Platelayers, }

(*a*) These to revert to their former duties, when the two new men came out, thus making 5 firemen.

(*b*) There were an insufficient number of these; at the Zoulla terminus, the storekeeper and the head clerk performed the duties of station master and assistant do.; at the Koomaylee terminus, these duties were performed by an artillery officer and (on alternate days) by the two sergeant overseers.

(*c*) It would have been preferable to have had military men instead of civilians for clerks.

(*d*) One temporary, to be discharged on relief of the original six, one had died.

(*e*) Of the original six, one had been promoted to engine driver; two were acting. The salaries of these men were the same as on the Indian railways, at least, so I am given to understand.

Working parties

On an average there were two left wings of Native Regiments, and two complete gangs of the Army Works Corps, when, from the nature of the work, extra hands were put on, there was a third gang of the latter, and a wing of a European regiment, when the work was completed and maintenance only was required, we had only one gang of the Army Works Corps Besides actual work on the line, the two wings furnished guards and working parties to all the wells along the line A gang of the Army Works Corps was rather stronger than a company of Sappers

Native Subordinates

	1	Maistry, } Platelayers		3	Rivetters
	3	Muccadams, } Platelayers		2	Holders
	54	Coolies, } Platelayers	(*a*)	20	Hammermen
	2	Clerks		14	Carpenters
	7	Fitters	(*b*)	12	Signallers
	2	Brakesmen	(*b*)	12	Pointsmen
	1	Foreman Fireman	(*d*)	12	Native Engine drivers (en route from Bombay—not joined)
(*c*)	15	Firemen			
	2	Springsmen			
(*a*)	20	Smiths			

(*a*) There was an excess of smiths and hammermen, this excess, about 12, were employed as night cleaners

(*b*) There was an excess of signallers and pointsmen, these, to the number of 8, were employed as messengers

(*c*) The excess firemen were employed on the portable engine, &c

(*d*) What these were intended for, I am unaware, they arrived in time to be too late

Yours truly,

ROBERT PENNEFATHER

No. CCII

ROPE BRIDGE OVER THE CHENAB.

From LIEUTENANT JOHN CHALMERS, *Deputy Conservator*, *to* DR. J. L STEWART, *Conservator Forests, Punjab*

Chumba, 20th November, 1867

I BEG to forward a sheet of drawings by Mr Sparling, of the bridge at Kilar, over the Chenab

The sheet contains—1st, A full side view of the bridge, as it at present stands, but on a small scale, 2nd, An enlarged plan of one end, showing the framing and the arrangement of the ropes and their fastenings, also the suspending arrangements, flooring and foot guards, 3rd, A longitudinal section of one end on an enlarged scale, which also shows the framing and the arrangements for securing the ropes, 4th, A cross section The timber used was *deodar*, except when ash is noted in the drawing

The scale will give the scantlings

The ropes, 7 in number, are made of very good native soothe (hemp), tarred and twisted into hard cable laid rope At present after having been up 17 months, they are about 2½ inches in diameter, when first made, they were about 3 inches The strength I calculated from Molesworth's Pocket-book, taking an extreme weight, making great allowances for assumed inferiority of native material and workmanship, and still greater for contingencies, but as I have not the book here, I cannot give the exact data on which I went That the present strength is ample, is however proved by the fact that the bridge has at one time had as many

as 14 cattle and their drivers, on it, and that up to this time there is not the slighest sign of straining in any part

Pulleys for tightening the ropes would, no doubt, save labor, but the making of them requires skilled workmen, which Mr Sparling could not spare at the time, and as the ropes have had only once to be strained during 17 months, we have not found the want of them much The straining was easily effected by about 30 coolies caught on their way to their ordinary work, and, as far as the ropes were concerned, was completed, and the men released within half an hour

The former drawing sent, was made when the bridge had considerable curvature from the stretching of the new ropes, it is now very nearly level, indeed so much as to seem quite so to the eye of a person crossing, and neither horses nor cattle make any objection to it An upward camber would entirely remove the very considerable supporting power of the three roadway cables, and thus necessitate stronger upper ropes, but it can easily be done if preferred

The supporting ropes at one end of the bridge form equal angles with the pier, or very nearly so, and this is desirable in every case, but its attainment at the other end would, from the conformation of the rocks, have involved an amount of blasting we had not the means of executing

The abutments are constructed of the ordinary masonry of these hills, viz, a wooden framing of crossed logs, fastened securely together with pegs, and the interstices filled up with stone This is very durable, as I have seen a bridge in Cashmere, the abutments and piers of which are of the same sort, and which is said to be 400 years old It is not injured even by severe earthquakes, and it will withstand a strong rush of water It has also this additional advantage, that no lime is required, and that the ordinary coolies of the country can build it

The only improvement that has suggested itself to us since the bridge was built, arose from its use by horses and cattle, which was not originally intended It was to nail cleats on the planking, and add boards 6 inches wide and $\frac{3}{4}$-inch thick at each side as foot-guards This was done three months ago

The bridge has now been upwards of 13 months in use, the traffic is very great, and not a single man's labor has been expended on repairs, whilst the old jhula* used to take at least 20 laborers daily to keep it

* Native rope-bridge

in repair during the summer season, and even then was from the great traffic often impassable for days together

Mr Watson, C E, of the Madhopoor Workshops, from his experience in the Plains, expressed an opinion that the ropes would not last over a year without renewal I am happy to say that they are now as sound and much harder and firmer than when put up, and I am satisfied that, if taken care of, and occasionally tarred, they will last for very many years yet

Statement of estimated cost of constructing the rope-bridge over the Chenab River at Kilar in 1866

		R	A	P
Paid for, ...	2,035 maunds of soothe at Madhopoor,	206	4	0
	Carriage to Panjee from Madhopoor,	62	7	9
Estimated, having been done by the Forest employees during the time of snow,	Making tar, .	23	0	0
	Putting up twisting machinery, .	12	0	0
	Twisting cables, suspending, &c,	37	0	0
	Ash-pieces for foot-way, .	2	0	0
	Planking 2 feet road-way by three-fourths of an inch,	12	0	0
Estimated, done by *begaree*, or free labor chiefly,	Blasting and clearing at one side with framing abutment, and framing at the other side, ...	310	0	0
	Total Rs, .	664	11	9

The three roadway cables are crossed, at intervals of 1 foot, by $1\frac{1}{2}$ inch rouse-wood sticks, similar to ladder rungs These sticks are firmly lashed to the cables with tarred soothe, and their ends project 3 inches beyond the cables at each end The vertical ropes are lashed round both the sticks and outer cables, as shown in enlarged section

The planking is sound clean deodar, $\frac{3}{4}$-inch thick, and notched at intervals of 6 inches on the upper side to afford a secure foot-hold, the notches commencing from the centre, this also makes the planks bend to suit the curvature of the bridge The planks are simply laid on the cross sticks and lashed down to them with tarred soothe, through holes at each side, at intervals of 6 feet

It is intended to remove the planking in winter to prevent a heavy accumulation of snow, as the only traffic then is unladen foot passengers, who it is found, travel easily on the cross sticks

They are turned twice round a log of wood fastened under a heavy frame-work, weighted down by the upper 4 feet of the abutment, and

belayed Should it be necessary to tighten them up, it is easily done one at a time, to any required extent, 25-coolie-power is required do it without a windlass, which, however, we should make if we had other bridges to construct

The side netting is composed of 4-inch meshes made of tarred soothe, 3 strands twisted together, and with a thin rope at the bottom and top If I had to make another, I should have the net of 3-inch meshes and of 6 strands of soothe, for although the present one is quite strong enough, it looks slight, and a closer and thicker net would give more confidence

I may also mention that were I to make another such bridge, I would make the roadway $2\frac{1}{2}$ feet broad instead of 2 feet The present one was only intended for coolies, sheep and goats, but I find it is now extensively used for cattle, 14 of which have been seen on it at one time, and for them it would be the better of 6 inches extra breadth

I need not say that it would have been better engineering to have put the strength of the upper sustaining ropes into 2 ropes, one on each side, instead of 4, as I have done, but I could, with my rough machinery, not twist satisfactory ropes over 6 inches in circumference

J C

No CCIII

NAVIGATION OF THE SEINE

From A M RENDEL, ESQ, *to* COL STRACHEY, R E, *Inspector General of Irrigation Works.*

Dated 26th March, 1868

You will remember that, whilst I was in Calcutta, you and I had some conversation relative to the haulage of boats in canals by means of a chain laid along the bottom of the canal, and that I told you that some such system was in use on the Seine.

It so happened that I had to spend last Sunday in Paris on my way home, and that, as I was walking along the river bank, I saw this system in operation

I was not sufficiently close to be able to observe details very accurately, but this is the result of my observation

The chain appeared to be the common short link, made out of $\frac{3}{4}$-inch or $\frac{7}{8}$-inch iron, the train, which was hauled along it, consisted of three boats about 100 feet long × 18 feet or so wide, of what draft I don't know, probably about 4 feet The leading boat contained the motive power, consisting of a steam-engine working two drums, over both of which the chain was passed by a sheave in the bow with apparently a couple of turns round each drum It then passed out over the stern by another sheave and dropped into the river The two other boats were, of course, towed by the leading boat

When I saw the train first, it was at rest, but shortly after, the engine was set agoing, and the train moved off at the rate of about 3 miles an hour against a stream of, perhaps, two more It passed easily enough

under the bridges, the leading boat being provided with rudders at both ends, by the use of which the chain can apparently be deposited in whatever part of the bed of the river may be desired

From the cases of the wheels by which the drums were worked, I learned that the leading boat belonged to the Compagnie Anonyme de Tonage de la basse Seine et l'Oise I have no doubt, if you wished it, you could get full particulars through the India Office of construction and economic results, and I have little doubt that the system is applicable to your canals

---

Memorandum regarding the system of haulage by means of a submerged chain, as practised in the navigation of the River Seine

THE system of towing a train of barges by means of a submerged chain has been in operation on the River Seine since 1854, when a chain was laid down from Paris to Conflans, a distance of 72 kilometres, or 41 7 miles In 1863, a second system was established reaching from Conflans to Rouen, and from Rouen to le Trait, the latter place being about 59 kilometres, or 36 6 miles from the sea The distance from Conflans to Rouen is about 173 kilometres, or 107½ miles, and from Rouen to le Trait, 57 kilometres, or 35½ miles,—the total distance being about 143 miles

From these figures it will be seen that the system in question is now, and has been for some years, in operation over a considerable extent of river navigation, and, we are given to understand, with very satisfactory results

Without entering into a detailed description of the mechanical arrangements of the system as at present practised, its general features may be described as follows —

An ordinary short-linked chain, made of iron, from 21 to 23 millemetres diameter (from 8 to 9 inch) is sunk in the bed of the river, and made fast at the extremities of the line The service is carried on by means of tug-boats and barges The tug-boats are fitted with a pair of engines driving by means of suitable gearing, two grooved barrels carried on a framing above the deck The chain passes over a pulley in the bow of the towing vessel, over supporting rollers above deck, round

the grooved barrels, and thence over rollers and pulley into the river astern The pulleys at each end are fitted in movable frames by means of which, in conjunction with the rudders, of which there is one at each end, the vessels are steered, and although at first sight it might appear that there would be some difficulty experienced in passing curves in the river, we are assured that such is not the case, and that the vessels and trains are completely under control

The gearing between the engines and grooved barrels is so arranged as to admit of two speeds of towing being employed, viz,—either 5 or 3 kilometres (3 1 and 1 8 miles) per hour The slower speed to give increased power of traction for heavy trains, or to enable an ordinary train, which would usually proceed at the quicker speed, to overcome the increased resistance at any part where the current might be stronger than usual

We believe from 2,000 to 2,400 tons of goods can be taken in one train at a time

The towing vessels employed by the Company carrying on the service from Conflans to le Trait, have the following dimensions —Length 131 feet, breadth 20 feet, depth 7 feet 9 inches Their average draft of water is 3 feet, with 10 tons of coal on board The engines are of a nominal power of 45 horses The boilers are cylindrical tubular, working to a pressure of five atmospheres Their heating surface is about 900 square feet

These vessels are also fitted with twin-screws driven by the same engines as work the towing barrels The screws are used for descending the river alone, or for moving about when not in connection with the chain

The barges have about the following dimensions —Length 130 feet, breadth 22 feet, depth 8 feet 9 inches , these carry about 350 tons each

In conclusion, we believe that, on the whole, the system has given satisfaction, although at first considerable annoyance was experienced by the failure of the chain, but we believe that now, when in the course of working, the weaker links have been gradually re-placed by others, that the annoyance arising from this cause has been greatly reduced, if not practically removed

For the successful navigation of a river, other than the Seine, no doubt various modifications, as to strength of chain, size, and power of towing

vessels, dimensions and draft of water of barges, &c, would require to be introduced, depending on the nature of the river, and in India, difficulty might be experienced from the shifting banks of sand covering the chain, but the system appears to be one which could probably be employed with great advantage in the navigation of some of the Indian rivers

GLASGOW, 19th May, 1868 } R NAPIER AND SONS

Extract from "The Engineer," of 15th February, 1867

In 1852-53 an experiment was made with a chain of about 2 miles long laid in the Seine at Paris, and used for some time to tow barges through a part of the city, where, from the construction of the quays, horse-towing was rendered difficult, more especially as the stream through some of the bridges was very rapid After many preliminary difficulties were surmounted, and the towing on this short line had become an evident success, the promoters of the system began to make arrangements for extending their operations, and a Company was formed to establish a chain from Conflans, at the mouth of the Oise (a distance of about 44 miles down the river) to Paris Guided by the experience obtained on the shorter line, not much difficulty was encountered in bringing this one into working order The physical conditions of the river continued the same throughout both sections of line, the current and depth were uniform, and the bed was sandy or soft, and very regular Rising in a comparatively level country, the Seine does not bring down the quantities of gravel and stones which are transported by streams coming from Alpine or other mountain regions, nor is it subject to sudden floods as they are It is, in consequence of the great regularity of its flow, coupled with the fact that its stream is too rapid in general for economical towing by paddle or screw, that the Seine is peculiarly adapted for chain traction Immediately on the success of the Conflans chain, which very soon became apparent, there were proposals for the employment of the system on many other rivers, but none of the schemes brought forward were matured, and we believe the Seine continues to be the only river possessing this peculiar means of towing Its application to the Rhone was quite impossible, owing to the very tortuous nature of the navigable channel, and the irregularity of the current, besides, the great beds of gravel and stones, amongst which the river

runs, shift with every flood, and in some places a hundred or more yards of chain might be buried in a single night some feet beneath a sand-bank An imperial decree was obtained in 1856, for laying a chain from Lyons to Saint-Symphorien, on the Saone, but the project was abandoned from considerations similar to the foregoing In the same year, however, another imperial decree was issued to M de Heree, for the formation of the Compagnie du Tonage de la Haute-Seine, which, under the able management of M Callon, has had a flourishing career for the last ten years, and now performs the entire haulage on the river between Páris and Montereau, a distance of nearly 60 miles

The chain employed by this Company is manufactured at St Amant, in the Department du Nord The iron used for it is 18 mm (.709 inches) in diameter, the links being about $4\frac{1}{4}$ inches long It in no way differs in appearance from an ordinary chain cable of light weight, but the welding of the links is stated to be a matter of more special importance in chains for this purpose than for any ordinary use, as the vibration in passing rapidly round the drums of the windlass is soon fatal to a link in which the weld has the slightest imperfection * The chain is moored only at the ends, so that the 60 miles are all in one length, and a channel is cut for it in the sills of each of the 12 locks on the river between Paris and Montereau

The locks are 320 feet long, 50 feet wide, and have 5 feet of water over the sills They are however, only used when the river is low, and none of them raise the water more than about 2 feet

What the French call *un passage navigable*, *i e*, the main body of the river—passes beside them, and is always made use of when the level of the water permits It is a considerable drawback when the tow-er is obliged to go through the locks, as then her convoy of from 20 to 30 barges, ranging from 100 tons to 250 tons burden, must be separated into three or four sections, and much time lost This Company employ nine towing vessels, and very little variation has been made in the arrangement of the machinery for several years

To work a large traffic with several of these vessels on one continuous chain may, at first sight, seem a difficulty, but it is easily explained The tow-ers work each on a section of the line, and never pass one another, the train of barges being transferred from the custody of the ascending

boat to that of one which it meets returning from the delivery of the previous convoy at its destination We have no data for determining the length of chain "holding" on the ground as the towing barge advances, but it would seem to require only a very short length lying on the bottom to give the required resistance without coming "home" Were this not the case the "slack," which is practically unavoidable, would be a source of considerable difficulty, As it is, the effect of slack chain is not noticeable on the incoming chain, which is always strained by the effort of traction, but at those parts of the river where there are a few fathoms of chain more than the length of the ground requires, it does not run off the winding drums with the same facility that it does in reaches where the line is comparatively "taut" When this tardiness of paying out takes place, there is an accumulation of chain under the last groove of the after-drum, just where the chain enters the channel by which it runs out over the stern When this has gone on for a short time, so that there is a heap of perhaps 3 or 4 fathoms of chain tumbling over and over, apparently in imminent danger of becoming entangled, one of the bargemen comes with a piece of rope-yarn, and with great dexterity lashes a link which is just passing off the drum to one at the other end of the tangle, just emerging into the channel, and the whole "bight" is carried over the stern in an instant

The principal dimensions of the towing boat La Ville de Sens are as follows —Length over all, 131 feet, breadth over all, 23 feet, depth of hold amidships, 6 feet 10 inches, depth of hold near the ends, 4 feet, draft of water, 1 foot 4 inches, length of each boiler, 20 feet, diameter of each boiler, 4 feet, diameter of firebox, 2 feet 2 inches, length of firebox, 10 feet, length of tubes, 10 feet, diameter of cylinders, 15 inches, length of stroke, 32 inches, diameter of chain drums, 3 feet 7 inches, distance of axes, 8 feet 3 inches, ratio of gear, slow speed for towing, 2 25 to 1, quick speed for down-stream, 93 to 100, width of gearing entablature, 5 feet, width of engine entablature, 8 feet 2 inches

These boats are of 35 horse-power nominal, and do not indicate more than 100 horse-power when towing against stream, as we saw them, 28 barges ranging from 100 to 250 tons burden, but it must be observed that, most of them were light, having brought down goods to Paris, and returning empty The advantage of working from a fixed point, as compared with expending force on a fluid medium, is plainly seen in

this system, and is the mainspring of its success where its application is practicable The ends of these boats are similar to each other in every respect, but the boilers are not placed centrally, but just clear of the keel line on opposite sides of the vessel This is done in order that the funnels and steam domes may not interfere with the channels, by which the chain passes along the deck

The end of the channels, is movable, turning laterally on a pivot distant 11 feet from the centre of the sheave over which the chain passes in or outboard These radial guides traverse freely on pulleys, which run on an angle-bar laid on the edge of the deck, and adjust themselves to the direction of the chain, which is, of course, altered at every shift of the helm The channels, rollers, and all parts that come in contact with the chain, except the winding drum, are of wood In turning bends of the river, the tendency is always to pull the chain towards the inner bank of the curve, and the ascending boats do really shift it considerably nearer to a straight line than would do for another boat following to use, but this is corrected by the next descending boat, which, returning with a comparatively slack chain—for they do not tow down the river—and taking a wide sweep, re-places it in the centre of the navigation

The chain takes five coils round the drums, and even with this precaution there is sometimes a slip at starting, when an excessive strain takes place

The gear is shifted by means of a pair of screws, passing through the boxes of the driving wheels, and turned by pinions, which are actuated by a spur attached to a hand-wheel V

These boats have condensers, and work to a pressure of 65 lbs. of steam They are stated to consume only 2 cwts of Mons coal per hour, whilst towing at the rate of $2\frac{1}{2}$ miles an hour against a stream on an average of 2 miles an hour They can take barges containing 1,200 tons of freight under these circumstances

A miniature chain and towing boat are in use on the canal of La Villette, which goes from the Seine, just above the "Halle aux Vins" in Paris, to St Denis, a distance of about 12 miles down the river It cuts off a long bend of the stream passing by Sêvres and St Cloud, and is of great use to a large class of traffic coming up the river This canal was executed in 1823, and is a fine piece of work, with locks 160 feet long and 45 feet wide, and 5 feet of water over the sills During the present

reign it has been arched over for more than a mile to form the new "Boulevard Richard Lenoir," at the end of which is the place de la Bastille, directly under the famous column of which the canal passes Very few visitors to Paris, when admiring one of the most famous historical monuments in the world, are aware that a steam navigation for vessels of 400 tons exists beneath its foundations.

No CCIV

FLOODS IN THE NERBUDDA RIVER.

On the damage by floods to the Nerbudda Bridge, Bombay and Baroda Railway in 1867, *and the remedial measures adopted*

From C Currey, Esq, Agent, B, B and C I Railway Company, to Consulting Engineer for Railways, Bombay—Dated 24th August, 1867.

I have the honor to report that, commencing from the 19th instant, there has been a very heavy flood in the Nerbudda River, which has but slightly subsided up to the present time

The Nerbudda Viaduct has sustained little or no injury, but very considerable damage has been done immediately south of the viaduct to the embankment, in which there is one gap of about 300 feet, and other minor gaps, three bridges,—one of two spans of 60 feet, and two of 20 feet,—have also been carried away in the embankment

The Chief Resident Engineer is on the spot, and it has been decided to fill in all the smaller openings in the embankment, and to give extra waterway at the viaduct by adding six spans to the southern extremity of it,—a course which, I hope, will meet with the approval of Government

Upwards of 2,000 men are now at work on the bank, and it is expected that, by the 26th, it will be so far restored as to admit of passengers getting over the damaged length, (about two miles,) in lorries, except at two of the biggest gaps, *i e*, at the southern end of the viaduct, and at the place where the bridge of two 60 feet spans existed, which will have for the present to be carried on foot

To complete the restoration of the line for traffic will probably take about six weeks, there being upwards of 50,000 cubic yards of earth-work to re-place, as well as six spans of bridge-work (all of which is fortunately on the spot) to erect

From Capt H. F Hancock, R E, Dy Consulting Engr for Railways, to Consulting Engr for Railways, Bombay—Dated 26th August, 1867

I have the honor to report that I inspected the Nerbudda Bridge and the damaged embankment on the south of the river on the 22nd instant

The injury done to the bridge itself during the recent floods is trifling, and the structure stood the severe test to which it was exposed very satisfactorily Three detached piles, not under the road-way on the down-stream side, where broken. The piers in the deep water are now formed, as you are aware, of five piles instead of three, an extra pile up, and another down, stream, having been added recently, all the up-stream detached piles are sound, but one of the down-stream piles broke during a flood on the night of the 16th instant at the second joint from the top, and two more broke during the severe flood of the 19th, how far down is not known at present

The piles which have broken were only completed a little while before the monsoon set in, and had not been concreted It generally happens that the joints of new piles work lose after a little time, and although care was taken to tighten up all the bolts throughout the bridge just before the rains, it is probable the joints of these piles worked loose during the floods, and that the bolts have given way This is known to have been the case with the first pile which gave way on the 16th, but it has been impossible to get at the others yet

The heads of the detached piles were braced very strongly longitudinally and cross-wise, and it was thought they were secure, although the continuous cross-girders which are to connect the heads of the five piles of each pier, and which, I believe, will effectually prevent any oscillation in the detached piles, have not been fixed These girders are being made up in England, and a supply is expected immediately

Had the piles been concreted, they would, perhaps, have been firmer, but there was no time to concrete them before the rains The up-stream detached piles have stout wooden fenders braced to them, which no doubt add to their strength and stiffness, and although a quantity of heavy timber came through the bridge on the afternoon of the 19th, and every one was struck several times, they are uninjured

Steps were being taken to secure the broken piles down-stream, and to prevent their shaking the piers, chains had been passed round them, and they had been slung to beams projected from the down line of girders re-

cently erected, and men were engaged in detaching the bracings which held them to the rest of the pier When I was on the bridge, the flood was a few inches below the second pile joint from the top, 5 or 6 feet lower than it was on the 19th and 20th, and I could detect no shaking in any of the piers, even in those to which the broken piles were attached, beyond a slight tremble similar to that felt when a train is crossing The Engineer in charge, Mr Curling, and others who were on the bridge when the flood was at its height, informed me that the bridge was then equally firm, and there can be no doubt the cluster piers have tended to strengthen it greatly, although they are not yet finished

The extreme south end of the bridge rested on piles screwed behind the end of the embankment, which was protected by a kind of curtain of brick pitching in mortar The pitching was done a good many years ago, I think in 1859 This and a quantity of new pitching done recently was scoured out by the flood on the 19th, the water, rushing round the end of the embankment with tremendous force, soon carried part of it away, and the piles supporting the end span of the bridge were exposed These piles were not screwed to any depth, but strange to say, they were not carried away, and were standing at the time of my inspection, but two of them had sunk 3 or 4 feet Mr Curling was making up a kind of derrick of iron piles, by means of which he intended to raise the ends of the girders and support them, till the piles could be re-screwed to a proper depth

On reference to the sketch it will be observed that the channel of the Nerbudda River was in ancient times about $3\frac{1}{2}$ miles further south than now, and that it is gradually shifting to the northward The Blind River possibly marks a former deep-water channel When the river is in flood, the whole of the low lying ground between the river and the high ground about Soorwaree to the southward is under water. The embankment then acts as a dam, and the water is pent up on the east side of the line, its only means of exit, besides the main river channel, being the small openings left between Soorwaree and the Blind River

The Blind River which formed the natural exit for the flood-waters has been stopped up by the embankment Originally it was intended to bridge this channel, but on consideration it was determined to add the number of spans designed for the Blind River to the bridge over the main channel of the Nerbudda This alteration, the expediency of which was concurred in by Government, was sanctioned, I believe, in 1858 or 1859.

On the 19th instant, the river rose to 33 feet above high-water spring tide—a greater height than it has been known to attain since the Railway was commenced The floods destroyed three out of the six small bridges in the embankment, crippled a fourth, and carried away a large piece of the end of the embankment nearest to the large bridge The current from the Blind River flowed due north along the east of the embankment to the Nerbudda, and due south from the end of the embankment back again towards the Blind River along the west side The cuttings formed for making the bank provided a ready-made channel The current was thus running in opposite directions on either side of the bank at the time of my inspection, and though the water had fallen considerably since the day before, was even then very rapid on the east side

The damage done to the embankment was as follows —About 350 feet of embankment, close to the bridge, completely gone, 300 feet more cut half through on the east side, and a large cut on the west side, a little beyond towards the south Proceeding southwards the bank has suffered slightly from scour on the west side where the earth-work is fresh, but altogether the damage is far less than I expected The thick covering of babool trees has effectively protected the east bank, and the new work on the west side, which was protected by a brush-wood covering, has escaped injury in a surprising manner

The 20-foot arch next the Blind River is uninjured, but a hole was scoured out just above the bridge on the east side, and the scour would have soon reached the masonry foundations had the flood continued

The next bridge had two 60 feet girder openings It formerly consisted of a single 60 feet girder on masonry abutments One abutment was scoured out and carried away in the flood of 1864, and Government sanctioned the re-construction of the bridge, and the addition of an extra span on piles this work was finished the same year or early in 1865 This year the other abutment was washed out, and one span of superstructure went with it The piles with the other span are standing in the middle of a big hole, full of water, some 300 feet wide, and 15 deep.

The next bridge was a single girder opening of 20 feet. It has been carried away bodily, and the material scattered. A large hole, about 60 feet wide, scoured out where the bridge was

The next bridge, a 20-feet arch, is standing, but the south abutment

and wing walls have evidently been undermined, and are cracked in all directions, and the arch is crippled

The next bridge of three 20-feet arches is apparently uninjured, though the scour had commenced, there are two cracks in the haunches of the second and third arches, but these appear to be of long standing

The next bridge was a single girder opening of 20 feet The south abutment was scoured out and gave way There was a gap here about 50 feet wide

The following steps have been decided upon by the Chief Resident Engineer —

1st —To add six spans to the Nerbudda Bridge This I have no hesitation in recommending, and my only doubt is whether it would not be well to add more

2nd —To stop up all the six small openings south of the Blind River This I also believe to be the only safe course, whatever may be decided as to the necessity for giving more water-way There can be no doubt, after the experience of this year and of 1861, that these small openings are most insecure, and quite unequal to carrying off the flood-water They are useful for roads, and if the Railway Company stop them up, they must provide proper crossings with ramps on each side over the embankment, and also must undertake to devise means of carrying off the flood-water from the cultivated lands to the eastward of the line rapidly, and prevent its accumulating I admit the latter is not a very simple business if the water is all to be led down to the Nerbudda River, but there is nothing impracticable in the scheme, and the Company had much better go to the expense of the necessary works than run the risk of a recurrence of disasters like the present, when their line is in full work and carrying the traffic of the North Western Provinces

As soon as the floods subside sufficiently, the Nerbudda Bridge will be examined by divers from end to end to see whether any bolts or bracings have given way under water.

RESOLUTION *by the Government of Bombay, in the P W Dept, Railway Branch* —Dated 2nd September, 1867

It appears that two 20 feet bridges, and one bridge of two 60 feet spans, in the southern approach bank of the Nerbudda Bridge, have been carried away; that one 20 feet bridge has been injured, that a length of 300 feet

of the bank adjoining the main bridge has been entirely breached, and that other parts of the bank have suffered more or less injury

The main bridge has not, as far as is known, been injured

There was no accident to trains

The cause of the failure was a flood which rose 33 feet above high-water spring tides, or to a height which it never before has been known to attain.

This flood appears to have set with great violence through the openings in the embankments, and to have taken a course parallel to the bank on the east side from the Blind River to the main stream, and in a reverse direction between the same points on the west side

It is probable that the bank would have suffered to a greater extent than it did from the oblique scouring action of the flood, had it not been protected in some parts by trees, and in others by a covering of bushes.

The course taken by the flood indicates the probability that, when the stream attains a certain height, an outlet at the Blind River is the best mode of passing it off safely, and that any reasonable addition to the main bridge would not prove entirely effective. This point has attracted the attention of the Consulting Engineer, and his further and early report on the subject is awaited in view to the adoption of any measures that may be considered necessary while the present restorations are being carried out

It is very satisfactory to learn that the main bridge has apparently suffered no injury, though the flood rose higher than that of 1864, which swept away six of the spans

This security has no doubt been obtained by the additional number of piles in the piers, but the lower works of the bridge should be carefully examined as soon as the state of the river will admit, and all the joints, nuts, bolts, and braces, should be minutely inspected

Government await the full report of this inspection

As regards the measures proposed by the Consulting Engineer, and authorized by Captain Hancock, Government doubt whether the addition of six spans to the bridge is the best application of the material, and whether it would not be better to place the spans, with such others as may be considered necessary, at the site of the Blind River. They desire, therefore, that the Consulting Engineer will take the subject immediately into consideration, and favor them with his advice

It is clearly necessary to stop up all the small openings, but proper crossing-places by means of ramps must be made, and whatever is effected, it

will be necessary to provide for the drainage of the land east of the bank, on both these points the Agent should be given clearly to understand that Government will insist, whatever plan of restoration may be adopted

---

From Colonel A DeLisle, R E, Consulting Engr for Railways, Bombay, to Agent, Bombay, Baroda and Central India Railway Company.—Dated 6th September, 1867

I have to acknowledge the receipt of your letter of the 31st August, and of the Chief Resident Engineer's interesting report on the damage done to the Nerbudda embankment These have have been submitted for the information of Government

I now forward copy of Government Resolution of the 2nd September on Captain Hancock's Report, and with reference to it, to request that the screwing of the proposed six spans in extension of the viaduct may be suspended, pending discussion as to the propriety of re-opening the Blind River, or otherwise

On this subject, I enclose a Memorandum on the probable results of entirely closing the openings in the embankment, and shall be glad to learn your views on this question, as well as those of the Chief Resident Engineer

---

Memo. by Colonel A DeLisle, R.E, on the subject of the Blind River at the Nerbudda Viaduct

The first proposal for closing up this channel by an embankment emanated from Mr Forde, then Chief Resident Engineer, in 1858. The following reasons for the alteration were given in his letter of the 14th April, 1859

" On reference to the plan, it will be seen that there is a curve at the crossing of the south channel, and that during the last monsoon the east side of the embankment suffered considerably from scour, in consequence of the position in which it stood, and that, by closing up this channel, these injurious effects will be obviated

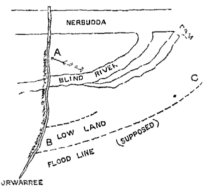
" The intermediate openings I would also close in order to reduce the scour and cutting of the embankment, and limit it to one point " *

At the same time, Mr. Forde proposed to throw the whole viaduct across the main channel of the Nerbudda by 59 spans in one length, instead of 44 spans on the main channel, and 15 on the Blind River

Mr Forde appears to have determined the amount of water-way by a section taken below bridge, but of the section there is no copy in this Office, and nothing to show what the configuration of the bed may have been The Chief Resident Engineer is, of course, well aware that this is an important item in the determination of the question of water-way, as a well defined and deep bed will carry off much more water than an irregular one of the same area. The viaduct was eventually constructed of 60 spans, to which another has been recently added at the north end

In 1864, the viaduct was damaged by a flood, and a strong scour took place through the small opening at Soorwarree, one of which of 60 feet span, failed, and was re-placed by 2 spans of 20 feet The Chief Resident Engineer, in his Report of the 3rd August, 1864, seems then to have intended recommending that the openings should be closed, and a side channel cut parallel to the bank to let off the waters through the ridge between Soorwarree and the Blind River. Nothing, however, appears to have been decided, and these measures were not carried out.

The Chief Resident Engineer now again proposes to close up all the openings in the embankment, and to add some 6 spans more to the length of the viaduct itself, to put a dam across the upper entrance of the Blind River, and minor dams across the channel below the embankment, and to cut a channel along the eastern side of the bank to pass off the waters from the low land near Soorwarree



The effect of these alterations will be to create a dead angle of water A, B, C, for which the only escape will be by the channel to be cut along the embankment, and to force the whole body of water through the viaduct openings, with a corresponding increase in the velocity of the current The fact of closing the openings of the embankment practically cuts off the natural escape for the waters in high floods, and introduces complications in the stream by bringing in a cross current along the bank at right angles to the direction of the river Captain Hancock states that this current was running

strongly northwards on the eastern side, and in the reverse direction on the western side up to the Blind River, and that there was an oblique current (indicated by an arrow) towards the piles at the southern end of the viaduct near A A difference of about 7 feet was also observed by Mr Whyte, when the flood was at its height, between the level of the waters on the east, above that on the west, of the embankment near Sooiwarice It is not quite clear either, that the proposed dam at the entrance of the Blind River would be of much benefit, as that channel would be filled by the overflowing of the low ground on which the Blind River and other channels are found

It is not known whether any observations were taken to ascertain the actual velocity of the stream during the recent flood For the present we can only estimate what the afflux and increase velocity would be approximately, assuming certain velocities for the unobstructed stream It is supposed that the flood of 1864 was ascertained to be running 13 miles an hour, and as on this occasion, it rose 4 feet higher, it will not be much exaggeration to assume that the stream ran 14 or 15 miles per hour through the bridge

Taking Molesworth's formula (Pocket-book, page 47) for afflux, we have—

	Square feet
Total area of bank and water-way to height of flood of 1867,	about 200,380
Water-way during flood of 1867, including gaps in bank and minor bridges, ...	„ 113,580
Water-way with openings in bank closed, but with six additional spans, .	„ 104,680

With these data, and successive velocities as shown below, we have—

Velocities.		Water-way with gaps as in flood of 1867		Water way with bank closed		Increase in	
Feet per second	Miles per hour	Afflux	Velocity	Afflux.	Velocity	Afflux	Velocity
		Feet	Miles per hour	Feet	Miles per hour	Feet.	Miles per hour
12	8	5.3	12	6.8	13.2	1.5	1.2
13	9	6.1	12.5	7.0	14.1	1.8	1.6
14	9.5	7.14	13.6	9.3	15.6	2.16	2.0
15	10	8.15	14.2	10.6	16.2	2.45	2.0

This Table shows that a velocity of about 10 miles an hour for the natural flood would give an afflux of about 8 feet, and a velocity of 14 miles an hour for the flood of 1867, with the gaps in the embankment, and that a similar flood would have an afflux of 10 6 feet, and velocity of 16 miles, with all the gaps in the embankment closed as proposed This increase of nearly $2\frac{1}{2}$ feet in height of afflux, and of 2 miles per hour in the velocity of the current, is a serious matter

Considering that the bed of the Nerbudda is known to have altered since the viaduct was erected, and that this year's flood is probably not the highest that may yet come down the river, the result of the above calculations would indicate the necessity of some caution before adopting, as final, the measures proposed by the Chief Resident Engineer If, for instance, spans were put in the Blind River (say 22 spans) and six more in the low level near Sooiwarree, the result with an original velocity of 10 miles would be (taking the water-way at 104,680 + 23,320) = 1,28,000—

Afflux	Velocity
6 3	1 275 miles,

which is less than the velocity of the flood of 1864, and is perhaps not an unreasonable current for a river like the Nerbudda

It might not even be necessary to give so many as 34 additional spans, if we could be sure that we had arrived at the maximum flood, but bearing in mind the possibility of still higher flood-levels, it seems only prudent to provide sufficient water-way to prevent any probability of the bank or viaduct being damaged Supposing, for instance, that a flood similar to the traditionary flood came down, the result would be as under, with an original velocity of 10 miles an hour—

	Afflux	Velocity
1st Case,—With the embankment closed up and six additional spans, .	$23\frac{1}{2}$	24 miles
2nd Case,—With 34 additional spans water-way 170,000, . . .	10	16 miles,

which last would certainly be the extreme limit of height that the bank could stand, and it is not unlikely that the waters would over-top the bank In the first case nothing could save the viaduct but the destruction of the bank

The calculations are very roughly taken out, and can only serve to give

an approximate idea of results, but there is quite sufficient to show the necessity for consideration before adopting the plan of closing up $3\frac{1}{3}$ miles of bank to the stream

I am of opinion, on consideration of the whole subject, that the proper course would be to give a liberal augmentation of the water-way rather than to endanger the existence of the bank, and perhaps of the viaduct itself, by completely cutting off the large extent of water-way which formerly existed in the Blind River, or low ground

The exact number of additional spans to be given is, however, a matter for discussion *Primâ facie*, it would seem better to put them in the Blind River where the depth is greater, than to extend the present viaduct over ground which now stands at a higher level, and would not give so much water-way per span.

There is no doubt some fear that openings in the bank at the Blind River and at the Sooiwarree might suffer from scour, but a liberal allowance of water-way, with proper arrangement of inverts and sheet-piling at the openings, would much reduce this danger The inverts should be continued a short distance above and below the openings so as to take the rush of water there.

From F Mathew, Esq, Chief Resident Engineer, to Agent B, B and C I Railway Company—Dated 20th September, 1867

With reference to your Memorandum enclosing copy of letter dated the 6th instant, from the Consulting Engineer to Government, I have the honor to report that the pile columns for the six additional spans on the south end of the Nerbudda viaduct were in site before I received the correspondence above referred to, but orders were given to stop the screwing, and the piles are now surrounded by the new temporary embankment On the work to be done in this case being sanctioned, the piles may be screwed home, and the bridge may be completed without stopping traffic

The pile pier at the south end of the bridge, which was protected by the old abutment pitching, was screwed to a depth of 6 feet only below surface As it was necessary to get a lower foundation for this pier, the superstructure was lifted, and the piles were screwed down 45 feet further, being to a depth of 5 feet into clay, and the superstructure has been replaced in a safe condition

The temporary embankment at the river edge, and the filling of the

other gaps made by the late flood, have now been formed, and the line for the train traffic throughout has been again restored.

As I have already reported, I am of opinion that it is essential to the safety of the line across the Nerbudda Valley, in the event of a recurrence of such a flood as has lately passed off, to have all the small openings back to Soorwarree closed, provision being made in the main river bridge for the waters of the Valley.

On the first point, as to the necessity for permanently closing all the small openings, there is now no difference of opinion, but whilst I propose to add the additional water-way which may be required at the river, the Consulting Engineer to Government proposes to re open the Blind River, and suggests a further smaller opening of 6 spans near Soorwarree.

I most fully concur that it is advisable to provide full water-way, and that nothing less than 22 or 24 spans of 60 should be put as an open at the Blind River. Upon this I forward herewith estimates in detail for 21 spans at the Blind River, and 6 at Soorwarree, from which it will be observed that these bridges, with such abutments as would be necessary, would cost Rs 8,61,000 (£86,000). The cost is not an argument against the construction, if these bridges can be shown to be necessary or sufficient, but I shall submit reasons for my opinion that these bridges would not be sufficient for openings in the positions, and that a far less amount of cost would afford at the main channel a far greater amount of water-way.

I have already submitted that the water-way proposed to be given in the Nerbudda is sufficient, and I now beg to refer to the calculations contained in Colonel DeLisle's Memorandum upon this subject, forwarding a section of the line across the Nerbudda Valley. I submit that the areas, upon which Colonel DeLisle's calculations were made, have to be amended, as under —

	(Unobstructed area)		Superficial feet
Total area of river and bank to height of floods superficial feet,	200,380	amended	235,790
Area of water-way during the flood of 1867, including all opens, .	113,580	"	147,930
Area of water-way with bank closed and 6 spans added,	104,680	"	142,640

With these amended data, by the formula used by Colonel DeLisle, we get as under—

Velocities		Water way with gaps as on floods of 1867		Water way with bank closed		Increase in	
Feet per second	Miles per hour	Afflux	Velocity	Afflux	Velocity	Afflux	Velocity
			Miles per hour				
12	8	3 84	11 7	4 32	12	48	3
13	9	4 51	12 47	5 1	12 85	59	38
14	9 5	5 2	13 2	5 85	13 60	65	40
15	10	6 2	13 81	7 0	14 21	80	37

The increase of afflux and of velocity in this case, it will be observed, is not of much account The calculation in this case may also be taken as under Taking the unobstructed area as represented by the flood of 1867 —1,47,9,30, and proposed area with 6 spans added to the river 1,42,640, we have the following results —

Velocities		Water way with bank closed	
Feet per second	Miles per hour	Afflux	Velocity Miles per hour
12	8	15	8 44
15	10	24	10 53
18	12	33	12 61

In Colonel DeLisle's paper, the area of the bank and water-way being taken to the greatest height of the late flood, the calculation would give, with a velocity of 10 miles per hour, an afflux or rise of 8 feet, or, in other words, would show that the height of water should have been 8 feet higher than the greatest height which the flood attained

The reasons given in Colonel DeLisle's Minute in favor of opening the Blind River, are, that a dead-angle of water would be created between the Blind River and the Nerbudda, the only outlet for which would be into the main stream, or rather, that the dead-angle of water, which would be caused between B and A on sketch, by closing the small openings, would be extended to C with the Blind River closed Colonel DeLisle further apprehends that the closing of the embankments would, by diverting the water which might otherwise pass through the embankment, cause a complication in the stream by bringing in a cross current at right angles to the direction of the river Such a current was, on the 21st of last month, after the flood had to a great extent subsided, observed running with considerable velocity through the old side-cuts into the river, but this was in a

confined channel, and whilst the flood was spread over the whole extent of low ground A, B, C and D, and flowing freely into the Nerbudda between C and D, it is not probable that there was any such rapid current However, to prevent any injurious effects from such a current close to the bridge, it is only necessary to form the cut, shown by dotted line on sketch, to direct the side-stream into the main channel sufficiently far above the bridge This channel, and the cross dams necessary to close the old side-cuts being formed, I see no reason to apprehend any ill-effects from diverting the water from low grounds near Soorwaree, into the main channel of the Nerbudda above the bridge

Whilst I do not see any necessity for opening a channel for the Blind River, there are, I submit, grounds for opinion that the measure would be a hazardous experiment It is a matter of general experience that by diverting even a considerable quantity of water from a large stream that the height and breadth of the stream are not reduced, but that there is a reduction in velocity In this case, the probable effect of a diversion of a portion of the Nerbudda waters into the channel called the Blind River, the material of the bottom of which is easily removable, and the channel of which up-stream has a greater slope than the main channel, being more direct, would be that the velocity of floods in the main channel would be reduced so as to allow of the formation of shoals, the result of which would be that future floods would be higher and more dangerous, not to the Railway bridge only, but to the lower part of the city of Broach The plan of the river shows the tendency which the currents have to straighten the river course, and with the Railway embankment on both sides of the Blind River to define the channel, there would be grounds for apprehension that, in time, a great part of the waters of the Nerbudda River would have to be accommodated in that channel by a bridge much more extensive than the bridge of 22 or 24 spans which has been proposed

It appears from these reasons, to be advisable to prevent the formation of the new channel, and it was with this view that I proposed to dam the Blind River up-stream, and not with any expectation such as Colonel DeLisle supposes, that a dam there would prevent flood waters from spreading over the low grounds from the sides of the Nerbudda

It is to be remembered that there has been, during several years, discussion upon this subject. At one time, apprehensions were entertained as to the effect of closing the Blind River, and that a flood flowing

through the Blind River channel at right angles to the Railway would cut through the embankment But after several floods, the result of the experience which has been obtained is, that the channel, since it was closed has been silting up, and that, whilst in the floods of 1864 and 1867, the outlets in the embankment which afforded narrow opens only for the high-flood waters, were at the ebb-tide cleared away, the solid embankment across the Blind River has been unaffected by the waters which it confined

I submit, upon the whole, that in this or any similar case, particularly where tide as well as land-flood has to be contended with, that the only safe course is to provide at the main outlet for the whole quantity of water, so as to render unnecessary small openings, which, with the country on both sides under flood-waters, would, on the outgoing tide, have an over-task to perform

Contrary to the result which would have been probable had a channel been open at the Blind River, the flood of the season has effected a considerable improvement in the main channel of the Nerbudda, by clearing away sand, as shown upon section, so as to afford an increase of water-way to the extent of 27,000 square feet or equal to 24 spans of 60 feet each, at the Blind River,—a work which would cost, as estimated, Rs 6,58,000 (£65,800) There is, at the present Nerbudda crossing, and in every new span erected on the south end, further room for similar action, and with a high velocity in the main stream, the channel is likely to be still further improved by a similar inexpensive operation, so as to increase the water-way to an extent much greater than has at any time been calculated as necessary

It is to be regretted that accurate observations were not made as to the velocity of the Nerbudda floods in 1864 or 1867 The velocities which have been reported were guesses only, and appear to have reference to the extreme velocity on the surface in the centre of the stream Whilst a high velocity has been assumed, it appears also to have been assumed that the openings, which were made after the bridge abutments had failed, existed as vents for the late floods when at its highest The fact was, however, that the unprotected earth-work at the gaps continued to be gradually carried away as the flood subsided

It may, however, be safely assumed that an area of water-way, such as existed after the late floods, would pass a similar flood without risk to the embankment or to the viaduct The embankment, at its lowest, is 10 feet above the level of the late floods, and the lowest part of the bridge

superstructure is 4 feet higher still, or 14 feet above the late flood level There is thus room for a considerable further rise of flood, and with a solid embankment and such a bridge abutment as shown upon tracing herewith, I submit that there are no grounds for apprehending risk of damage to the viaduct

In 1864, when five piers of this bridge were broken, each pier consisted of two half-braced pile columns only, whereas now, each pier consists of five-pile columns with double bracing throughout, and a substantial teak-wood fender up-stream to protect the piles from being affected by heavy drift During this season, these piers will be further strengthened by being fitted on top with a continuous girder, which will render the security of the superstructure independent of any one pile column The tracing of a complete pier herewith will serve to show how well-suited these piers, presenting a minimum of surface to be acted upon by flood pressure, and a maximum of strength in direction of the stream, are, to withstand any probable height and velocity of flood.

Upon the whole, I submit that it will be sufficient to add 6 spans of 60 feet, with a sufficient abutment to the south end of the Nerbudda viaduct, and I request sanction to the plan and estimate herewith for the work

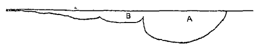
---

From Colonel A DeLisle, R E, Consulting Engr for Railways, to Secy to the Govt of Bombay—Dated 16th October, 1867

With reference to Government Resolution of the 2nd September, 1867, I have the honor to forward copies of correspondence regarding the late floods in the Nerbudda River at Broach, and the measures to be adopted in consequence of them

In my Memorandum of the 6th September, the areas and data were taken from a section of the river in the Office, and were much less than those now put forward by Mr Mathew, as the result of the scour caused by the late flood The height of afflux and velocities were consequently higher than those deduced by Mr Mathew from the more recent data available

But on further consideration it appeared to me that the formula for afflux would not apply with sufficient accuracy to a river bed like the Nerbudda, consisting, as it does, of two well defined portions—one deep, A, the other



shallow, B For the formula is constructed on the supposition that the discharge is proportioned, or nearly so, to the whole area, while in this case the discharge through the area A is much greater than that through the area B, and the calculated effect of closing B, as deduced from the formula, is consequently too great

It is, however, greatly to be regretted that no data exist upon which a reliable calculation can be based. A longitudinal section is given on the plan of the river bed, but this appears to have been entered in the reverse way, as it makes the stream run up hill, and no observations have been taken to obtain either the surface slope of the stream, or its velocity It is to be hoped the Railway Engineers will take immediate steps to provide all necessary appliances to enable them to record these observations at each of their principal rivers when in flood

The calculations must now be based in great measure on assumptions, for want of better data

We may assume the bed slope to be about 5 feet per mile as given on the plan, the surface slope would be greater, and may be taken at about 6 feet per mile. In the accompanying Table the results derived from these data are shown For the flood of 1867, I have taken the level one foot below what was actually observed, to allow for the partial obstruction

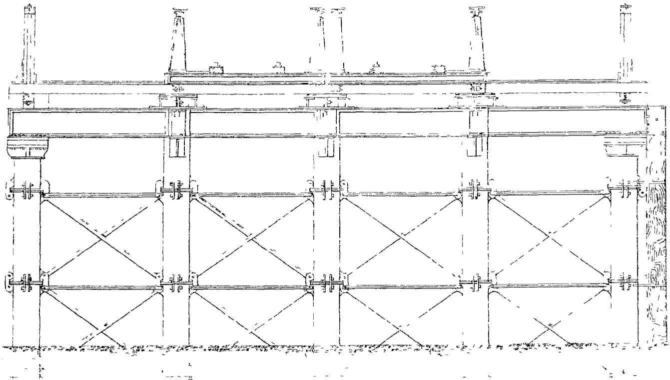
TABLE OF AFFLUX AND VELOCITIES, NERBUDDA BRIDGE

1	2	3	4	5	6	7	8	9	10	11
					VELOCITY					
Flood of 1867	Area in square feet	Perimeter wetted feet	Hydraulic mean depth area perimeter	Assumed slope feet	Inches per second	Feet per second	Miles per hour	Head due to velocity feet	Discharge in cubic feet per second Whole discharge through A	Discharge in cubic feet per second through A, including ⅔rd of that for area B
			Inches							
Bed of river A,	1,38,640	4,128	402	6	225	18 75	12 8		2,590,500	25,99,500
Shallow part B,	76,950	16,200	57	6	85	7 08	4 8	.	541,806	3,63,204
	Velocities and also for whole discharge through A				271	22 6	14 7	7 11	3,144,806	
Flood (traditional),	Ditto	Ditto A	⅔ B		257	21 4	13 9	7 1		29,62,704
Bed A,	1,85,240	4,140	535	6 5	270	22 5	15 8	7 11	4,167,900	
Shallow part B,	1,11,150	16,212	82	6 5	105	8 75	6	1 1	9,72,562	
					534	27 9	19	12	5,140,462	

The first line shows the velocities and discharge for the portion A, or

NERBUDDA VIADUCT-BRIDGE PIER COMPLETE.

Scale—8 feet to the inch.



deep bed The second line shows the same quantities for the shallow portion, B

The third line gives the velocities and afflux, supposing the whole discharge to pass through A only, and the fourth line is calculated on the supposition that one-third of the discharge of B passed through the gaps, or openings in the bank The difference between the last two lines will represent, approximately, the effect of closing these openings, viz, an increase of velocity of 1 2 feet per second, or 8 miles per hour, and an increased afflux or height of flood of 10 inches

These results are in themselves not objectionable, and are, to a certain extent, in accordance with such observations as have been made for a difference of level of 7 feet, as was observed between the up and down-stream sides of the embankment at Sooiwarree, and the velocity at the bridge was estimated at 15 miles in the centre of the stream, whereas our calculation makes it about 14

The result of the flood has been to scour the bed of A to a considerable extent, viz, about 3 to 4 feet in depth in the bed, and 16 to 22 feet for about 360 feet of the south bank The increase of area is estimated by Mr Mathew at 27,000 square feet, and over this portion bracings will have to be added to about two more lengths of piling which were formerly buried in the bed of the river

Now, if we calculate the same results for the traditional flood, we have, bearing in mind that in 1855 no Railway bank was in existence to obstruct the river, from the Table—

	Feet	Miles per hour
Difference of velocity with Railway bank closed per second,	5 4	4
Increased height of flood due to obstruction,	4 0	
Velocity of stream, .		19

The increased height of flood would bring the water nearly up to the top of the bank, and the effect of a velocity of 19 miles an hour on the bed of the river it would be difficult to estimate If 14 miles per hour has very much enlarged the channel this year, 19 miles per hour might have the effect of removing all the sand down to the bed of clay It is supposed that there are 15 to 40 feet of sand over the clay, and if this sand be washed away, and as the screws are only bedded 4 to 5 feet in the clay it is probable that the piles would not be able to resist the great pressure of the stream against a structure about 80 feet in height In fact, the safety of

the viaduct would only be ensured by the giving way of the earthen embankment.

I do not think, therefore, that a mere addition of six spans, which is only an equivalent for the length of bank destroyed by the last flood at the bridge-end, is sufficient, as it does not compensate for the gaps in the bank which are now to be closed up A large body of water, which I have roughly estimated at one-third of the discharge of B, found its way through these, and will now be thrown on the main outlet

If we could be assured that the flood of 1867 is the highest ever likely to occur, the six spans might be considered a *sufficient* addition to the water-way, now that it has been largely increased to a favorable form of section But we have no reasonable assurance that this will be the case, on the contrary, we have information of a still higher flood, and, under the circumstances, we should not do wisely in setting aside that information, though it may be more or less uncertain

As to the question of re-opening the channel of the Blind River, the objections raised by Mr Mathew are these—that the reduction in velocity in the main stream may cause shoals to be formed, secondly, that the effect of scour on the easily movable bed of the Blind River might make it the principal, instead of the subsidiary, stream

To the first objection I cannot attach much importance, as the slope and velocity of the stream are too great to render the formation of shoals during the flood season probable, and such deposits as might take place during the low season would be easily swept away by the first floods But the second consideration is a more serious one, experience has shown that, when a river divides itself into two channels, these are always in a state of variation, and it would be quite possible that the Blind River, if re-opened, might become the principal channel, which is not desirable

The Collector of Surat has requested that the interests of the cultivators on the low lands between Broach and Soorwarree may be considered. But it would appear—*first*, that these lands have always been subject to inundation during floods, *secondly*, that the effect of the Railway bank is only to increase the height and duration of the floods The only case in which the Railway bank could be said to act prejudicially would be that of a flood, which in the unobstructed river would have risen just below the level of the low lands without covering them, but which the embankment, by obstruct-

ing the water-way, would raise sufficiently high to flood them But even in this case the flood would be of short duration, and would probably not do much harm to the cultivation

We have no information before us to show to what extent such moderate floods occur, but the best test of the injury done to the cultivation by the Railway would be the rents now paid by the cultivators at the sales of the right to cultivate as compared with what they fetched before the construction of the Railway It has been already shown that the effect of closing the openings in the bank would be to raise the flood-level, as in 1867, about 10 inches, which would not materially affect the cultivation In fact, the only method of protecting these lands from flooding would be to embank the main stream and all its subsidiary channels This would not only be extremely expensive, but actually render the lands less valuable, as they owe their fertility to the fact of their being periodically flooded

The effect of closing the bank has, however, to be considered from another point of view The water rises in the dead angle nearly to the full level of the afflux caused by the obstruction, as shown by the observation made of the fall at one or two of the small openings, and this water can only be drained off by again passing into the main stream

Mr Mathew recommends that this water should be drained off by an artificial cut, delivering the water at a point above the bridge I regret that I cannot concur in his views, as the disturbance in the main current caused by another entering nearly at right angles, or even directed upstream, is objectionable The deep trenches shown in the section of the bed after the last flood are probably due to the action of these disturbed currents

I think the preferable plan would be to let the waters of the flooded ground subside into the main channel as a sheet without any deepened channels whatever, and for this purpose it would be necessary to close the side channel along the Railway by an embankment or dam, as proposed by Mr Mathew If the water thus retained in the channel of the Blind River is thought objectionable, a sluice may be provided in this embankment to draw the water off gradually, after the river has fallen

With respect to the low land near Soorwarree, there would be no objection to cut a drainage channel from its lowest level to the Blind River. This will obviate the necessity of the bridge at Oomerwarree, which is estimated to cost upwards of two lakhs.

The conclusions I have come to are, therefore—

1st.—That it would be undesirable to re-open the Blind River

2nd.—That instead of 6 spans, 10 or 12 spans ought to be added to the south end of the Nerbudda Bridge

3rd.—That no artificial cuts should made into the main channel to draw off the water from the lands on the east side of the embankment, and that the existing channels along the Railway Bank should be closed by embankments, with or without sluices, as may be determined

4th.—That with these precautions, the existing openings in the Railway embankment may be closed without danger

Mr Mathew proposes an abutment of piles for the south end of the Nerbudda, and considering the nature of the foundations, this appears to be the safest construction that could be adopted

I therefore recommend that the sanction of the Government of India be obtained to the following expenditure at the Nerbudda —

	Indian Expenditure	English Expenditure	Total
	RS	RS	RS
Cost of cast iron pile abutment,	22,105	26,271	48,376
Cost of additional spans with wrought iron-girders, ...	23,477	1,07,474	1,30,951
Total, .	45,582	1,33,745	1,79,327

and that the Chief Engineer be requested to submit a supplementary estimate for 4 or 6 additional spans, and of the cost of embanking the side channels cut from Oomerwaree to the Blind River, and of the level crossings, all of which works appear to be legitimately chargeable to capital

---

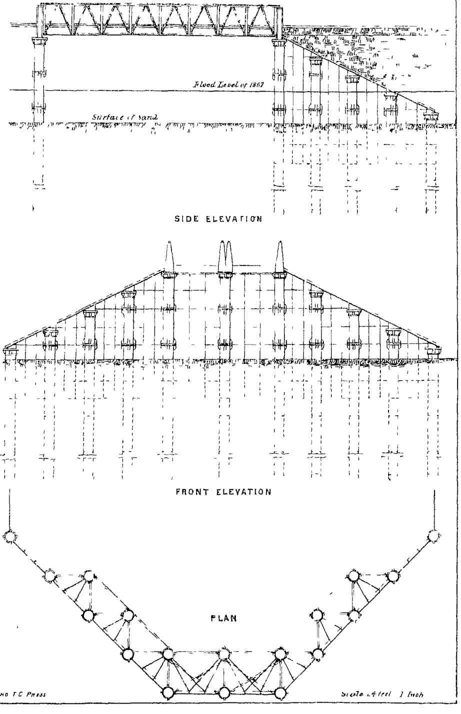
Resolution *by the Govt of Bombay*—Dated 3rd December, 1866

Government accept the calculations of Mr Mathew, the Chief Resident Engineer, and concur with him in thinking that, if 6 spans be added to the bridge with a strong southern abutment, it will not be necessary to open the Blind River, and that the small openings may be safely closed

The abutment suggested seems suitable, except that, to provide for any

FLOODS IN THE NERBUDDA

PROPOSED CAST-IRON PILE ABUTMENT FOR THE NERBUDDA BRIDGE.



future deepening of the hole that has been scoured at the south end of the bridge, it would be safer to carry the iron sheeting further down, say, to the level of the bottom of the next pile length, and with a view to enabling the abutment better to resist the great pressure that may be brought on it in the event of such deepening taking place, an additional row of piles should be added in the rear, and connected with the two front rows

As regards the drainage cut, Government concur with the Consulting Engineer that it would not be advisable to lead it along the toe of the embankment, but there seems no objection to carrying it along the dotted line suggested by Mr Mathew As an additional precaution, and, in order to place the eddy, which evidently takes place at the junction of the flow from the flooded land with the main stream, as far away from the bridge abutment as possible, it might be advisable to run out a spur at right angles from the embankment near the south abutment to a point, say, on the boundary of the cultivated land The effect of this spur would be to remove the eddy referred to, to a point above the bridge, and though the rush of the stream round the end of the spur would occasionally cause damage to it, such damage would be slight as compared with any injury to the bridge or embankment, and could be repaired from time to time

---

From C Currey, Esq , Agent B , B and C. I Railway, to Consulting Engineer for Railways —Dated 28th February, 1868

I have the honour to forward you an extract of Despatch from my London Board, together with a copy of a letter from Colonel J P Kennedy, the Company's Engineer, on the subject of the measures which have been agreed upon for the greater security of the Nerbudda Bridge and Embankment, and the number of spans to be added to the bridge

You will observe that the Directors concur with Colonel Kennedy, that 12 spans instead of 6, should be added to the bridge, and in deference to their instructions, I beg to submit an estimate, for the 6 extra spans, amounting to Rs 1,83,121, accompanied by a copy of a letter of the 27th instant, from the Chief Resident Engineer, thereon, for the consideration and sanction of Government

Mr. Mathew retains his opinion that 6, not 12, additional spans are quite sufficient, and he also fears it will not be possible to complete more than 6 during the present season. I shall transmit Mr Mathew's com-

munication for the further consideration of my Board and Consulting Engineer

---

From T Mathew, Esq, Chief Resident Engineer, to Agent, B, B and C I Railway —Dated 27th February, 1868

I have already submitted opinion that the additional spans in this case are not necessary, and that the extension of the bridge as sanctioned would be perfectly sufficient The Company's Consulting Engineer, in a former letter, appeared to entertain the same opinion, but for reasons which, I think apply also to other bridges which are not proposed, and do not, I consider, require to be extended, has now recommended 6 additional spans

Under ordinary circumstances, the measure would be a safe one, but the work proposed to be done in this case is of unusual difficulty, as has been already experienced in the work now in progress for the addition to the Nerbudda The actual depth from the top of the embankment to the bottom of the sand through which the piles have to be screwed, is from 67 to 71 feet, and the piles are so close to the lines of rails, that keeping the line open and working at the same time, it is necessary to remove the collar arms to allow each train to pass A pile broken in screwing in this case would involve a very serious expense, and a delay still more serious, so that the utmost caution is necessary, and with the utmost exertion in the matter, it will not be possible to have more than the 6 spans, which were before sanctioned, ready by the end of March In the season now approaching, when numerous cotton trains will be passing, it would not, I fear, be possible to complete the other 6 spans this season, even if materials were available

I much regret that, under the orders in this case, the construction of the abutment cannot now be commenced as before proposed, but I will consider what can be done as a temporary work to protect the embankment during the next monsoon

---

From Colonel A DeLisle, R E., to Secy to the Govt of Bombay.—Dated 17th March, 1868.

I have the honor to forward copy of letter of the 28th February, from the Agent, Bombay, Baroda and Central India Railway Company, and accompaniments, from which it appears that the Company's Consulting

Engineer, Colonel Kennedy, has recommended the addition of 12 spans at the south end of the Nerbudda Bridge instead of 6 spans as sanctioned, and that the London Board have ordered the addition

I shall be glad to know whether Government are disposed to sanction the additional 6 spans My own opinion is that they are necessary, as stated in my letter of the 16th October, 1867, and this opinion has been confirmed by further reports of the effect of last year's floods on the bed of the river I may add that reports recently received, which I shall lay before Government as soon as possible, show that some of the piles of the old bridge were not screwed to the depth supposed, and that many of them are not screwed into clay, so that it is doubtful whether they are altogether beyond the reach of scour

The difficulties of screwing the piles at the south end of the bridge are no doubt very great in consequence of the inconvenience of the situation for working, the extraordinary depth of the foundations, and the frequent interruptions to the work caused by trains, but I do not consider that the expense ought to deter us from carrying out the work, as I believe it is needed for the security of the bridge

As explained by Mr. Mathew, more than six spans cannot be completed this season, the other six will have to be put in next year, and meanwhile, some temporary arrangement will have to be made for securing the end of the embankment, pending the construction of the pile abutment This, as stated by Mr Mathew, is under consideration

---

RESOLUTION *by the Government of Bombay*—Dated 27th March, 1868

As regards the six additional spans, Government are inclined to concur with the Chief Resident Engineer that the 6 spans already sanctioned, especially with a strong southern abutment, are sufficient for the security of the bridge, but there can be no doubt that 12 spans would render it still safer, they will not, therefore, refuse to sanction this number according to Colonel Kennedy's suggestion, approved of by the London Board

Government will await the Consulting Engineer's Report, regarding some of the piles which are stated not to have been sufficiently screwed This defect, if it exist, is very serious, and demands the earliest attention of the Consulting Engineer and the Railway Company's Officers, and no time should be lost in laying the state of the case before Government, and in applying a remedy.

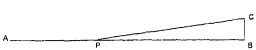
No CCV.

ON THE MOTION OF A RAILWAY TRAIN UP AN INCLINE.

To the Editor

SIR,—The following solution of a problem which has sometimes been discussed by engineers may interest some of your readers —J. H P

A train passes A at a velocity V, moves along the horizontal line AP, and up the incline PC AB $= a$, BC $= h$ (a small height, such that the



square of h may be neglected in comparison of the square of a) To find the position of P, that the time of passage from A to C may be the least possible The force of the steam is to be the same throughout, and the resistance of the air and constant effect of friction to be taken into account

The resistance of the air against a surface of one square foot moving in a direction at right angles to its plane with a velocity measured by the number of feet in one second equals a pressure of 0 002288 (velocity)^2 lbs * The weight of the train will be taken to be 100 tons. The area exposed to the resistance of the air 80 square feet

One foot velocity in one second $= \frac{15}{22}$ mile in one hour If then the units of distance and time are changed to one mile and one hour, the moving force of the resistance on each square foot $= 0\ 002288 \times \left(\frac{22}{15}\right)^2$

* *See* Molesworth's Pocket book of Engineering Formulæ

(vel)^2, velocity being the number of miles in one hour, and if $\frac{1}{m}$ (velocity)^2 represent the retarding force of the air on the train

$$\frac{1}{m}(\text{velocity})^2 = \frac{\text{resistance}}{\text{mass of train}} = \frac{0\ 002288 \times g}{100 \times 20 \times 112 \text{ lbs}} \left(\frac{22}{15}\right)^2 80 \ (\text{vel })^2 \text{ lbs}$$

$$\therefore\ mg = \frac{700000000}{572} \left(\frac{15}{22}\right)^2 = 568900.$$

Now, for the units we have chosen, g or gravity $=$ twice the space in miles described by a body falling from rest in one hour But a body falls 16 feet in one second hence in one hour, or 3600 seconds it falls through 16 (3600)^2 feet

$$\therefore\ g = \frac{16\,(3600)^2}{5280} = 39273$$

$$\therefore\ m = \frac{568900}{39273} = 14\ 5 \text{ nearly}$$

Let AP $= r$, PC $= s$ then as the square of h, or BC, is neglected,

$$r + s = a, \qquad \ldots\ldots \qquad (1)$$

a will be supposed never to exceed 5 miles and therefore $\frac{a}{m}$ is not more than one-third

We may neglect the change of velocity at the point P in moving from the horizontal to the incline, as it will vary as the versine of the angle of incline and therefore as the square of h

Let V and U be the velocities at A and P; also let F be the excess of the force of the steam over the friction and the resistance of the air at A let f be the excess of the force of the steam over the friction, the effect of gravity, and the resistance of the air at the point P, when the train is on the incline then

$$f = \text{F} + \frac{\text{V}^2 - \text{U}^2}{m} - \frac{h}{s} g \ \ldots\ldots\ldots\ldots \ (2)$$

We will first calculate the motion up the incline, because the motion along the horizontal can be obtained from the same formulæ.

Let x be the distance of the train from P up the incline at the line t Then the equation of motion is

$$\frac{d^2 x}{dt^2} = f + \frac{\text{U}^2}{m} - \frac{1}{m}\left(\frac{dx}{dt}\right)^2$$

$$\therefore \frac{\frac{d}{dt}\left(\frac{dx}{dt}\right)^2}{\left(\frac{dx}{dt}\right)^2 - \mathrm{U}^2 - f\,m} = -\frac{2}{m}\frac{dx}{dt}$$

$$\therefore \left(\frac{dv}{dt}\right)^2 = \mathrm{U}^2 + f\,m + \text{constant}\; e^{-\frac{2x}{m}} = \mathrm{U}^2 + f m - f m\, e^{-\frac{2x}{m}}$$

since velocity $= \mathrm{U}$ when $x = 0$

As x increases the greatest value (velocity)^2 can attain is $\mathrm{U}^2 + f\,m$, or by (2), $\mathrm{V}^2 + \mathrm{F}\,m - g\,m\,\frac{h}{s}$. This on the horizontal is $\mathrm{V}^2 + \mathrm{F}m$. We shall assume that the speed of the train is not greatly increased in passing from A to P, or that $\mathrm{F}m$ is small compared with V^2; also as f is less than F and U greater than V, $f\,m$ is small compared with U^2, and the squares may be neglected

$$\text{Now } e^{-\frac{2x}{m}} = 1 - \frac{2x}{m} + \frac{2x^2}{m^2} - \frac{4x^3}{3m^3} + \ldots$$

and $\frac{x}{m}$ is never so much as $\frac{1}{3}$ the cubes will therefore be neglected and

$$\left(\frac{dx}{dt}\right)^2 = \mathrm{U}^2 + 2fx - \frac{2f}{m}x^2 \quad . \qquad (3)$$

$$\therefore t = \int \frac{dx}{\sqrt{\mathrm{U}^2 + 2fx - \frac{2f}{m}x^2}}\;\sqrt{\frac{m}{2f}}\;\cos^{-1}\left(\sqrt{\frac{f\,m}{2\,\mathrm{U}^2 + f\,m}}\right.$$

$$\left.\left(1 - \frac{2x}{m}\right)\right) + \text{constant}$$

$$= \sqrt{\frac{m}{2f}}\left\{\cos^{-1}\left(\sqrt{\frac{f m}{2\,\mathrm{U}^2 + f m}}\left(1 - \frac{2x}{m}\right)\right.\right.$$

$$\left.\left. - \cos^{-1}\sqrt{\frac{f m}{2\,\mathrm{U}^2 + f m}}\right)\right\}$$

$$= \sqrt{\frac{m}{2f}}\;\sin^{-1}\left\{\frac{\sqrt{f m}}{2\,\mathrm{U}^2 + f m}\left(\sqrt{2\,\mathrm{U}^2 + f m - f m\left(1 - \frac{4x}{m} + \frac{4x^2}{m^2}\right)}\right.\right.$$

$$\left.\left. - \sqrt{2\,\mathrm{U}^2}\left(1 - \frac{2x}{m}\right)\right)\right\}$$

$$= \sqrt{\frac{m}{2f}}\,\sin^{-1}\left\{\frac{\sqrt{2fm}\,U}{2U^2+fm}\left(\frac{2U^2+fm}{mU^2}\,x - \frac{2U^2+mf}{2mU^4}\,fx^2\right)\right\}$$

$$= \sqrt{\frac{m}{2f}}\,\sin^{-1}\left[\sqrt{\frac{2f}{m}}\left(\frac{x}{U} - \frac{fx^2}{2U^3}\right)\right]$$

$$= \frac{x}{U} - \frac{fx^2}{2U^3} \quad \ldots \quad (4)$$

neglecting small quantities of higher orders as is done all along

If f were negative the integral would involve logarithms, and not cosines and sines But when expanded, as above, the result would be the same as here obtained

Putting V for U, F for f, r for x in (3) we have,

$$U^2 = V^2 + 2Fr - \frac{2Fr^2}{m}$$

$$\text{and } \therefore f = F - \frac{2Fr}{m} - \frac{gh}{s}$$

Hence by (4)

$$\text{time from A to P} = \frac{r}{V} - \frac{Fr^2}{2V^3}$$

$$\text{,, P to C} = \frac{s}{U} - \frac{fs^2}{2U^3}$$

$$= \frac{s}{V}\left(1 - \frac{Fr}{V^2} + \frac{Fr^2}{mV^2}\right) - \frac{s^2}{2}\left(F - \frac{2Fr}{m} - \frac{gh}{s}\right)\frac{1}{V^3}$$

$$\left(1 - \frac{3Fr}{V^2} + \frac{3Fr^2}{mV^2}\right)$$

$$= \frac{s}{V} + \frac{ghs}{2V^3} - \frac{F}{V^3}\left(rs - \frac{r^2 s}{m} + \frac{s^2}{2} - \frac{rs^2}{m} + \frac{3ghsr}{2V^2}\right)$$

$\therefore$ T, or time from A to C, as by (1) $r + s = a$

$$= \frac{a}{V} + \frac{gh}{2V^3}(a - r) - \frac{F}{2V^3}\left[a^2 + (ar - r^2)\left(\frac{3gh}{V^2} - \frac{2a}{m}\right)\right]$$

$$= \frac{gha}{2V^3}\left\{\frac{1}{2} - \frac{r}{a} + \frac{Fa}{V^2}\left(3 - \frac{aV^2}{mgh}\right)\left(\frac{1}{2} - \frac{r}{a}\right)^2\right\}$$

$$+ \text{constant}, \ldots \quad (5)$$

$$\text{Hence } \frac{dT}{dr} = -\frac{gh}{2V^3}\left\{1 + \frac{2Fa}{V^2}\left(3 - \frac{2aV^2}{mgh}\right)\left(\frac{1}{2} - \frac{r}{a}\right)\right\}$$

$$\frac{d^2T}{dr^2} = \frac{Fgh}{V^5}\left(3 - \frac{2aV^2}{mgh}\right)$$

and when T is a minimum

$$r = \frac{a}{2} + \frac{V^2 \, mgh}{2 \, F \, (3 \, mgh - 2 \, aV^2)}$$

and the point P must be on the right hand of the midpoint between A and C or the train must move more than half the distance horizontally before it begins to ascend

If $3mgh$ is less than $2aV^2$, then the second term of r is negative, and r is less than $\frac{1}{2}\,a$ In that case T is a maximum, and has no point of minimum but (5) shows that the larger r is (consistently with small quantities being neglected) the less is T and therefore in both cases there is a point to the right of A, from which if the incline begins, the time of reaching C will be less than if the rise begins at A or at any other place where the angle of the incline would be less than at that point

The subject is one of theoretical interest No doubt the time gained by taking one incline rather than another, within the limits of the approximation, may be too trifling to make the matter of any practical importance and there is this counteracting circumstance, that the *velocity* at C will be somewhat smaller the greater the incline is This can easily be deduced from formula (3).

MUSSOORIE, \
Sept. 9th, 1868.

No CCVI

IRON SLUICE GATES FOR RESERVOIRS

Designed by E B CARROLL, ESQ , C E

Memorandum on the adoption of High Masonry Dams, fitted with Under-sluices, for the purpose of forming Reservoirs on the Dekkan rivers. BY LIEUT.-COL J. G FIFE, R E.

ROCKY as the character of the Dekkan rivers is, it has nevertheless been found impossible to find a sufficient number of sites suitable for forming reservoirs on the ordinary plan, i e, by means of a high dam of earth or masonry thrown across the valley, with a separate waste weir, situated on a rocky saddle, over which the waste water may be discharged with safety

The occurrence of barriers of rock of more or less elevation across the beds of the rivers is very frequent There are also numerous spots where contractions in the width of the valleys occur, but it rarely happens that a suitable rocky saddle can be found near such spots for the formation of the waste weir, and, without such a saddle to discharge the waste water over, reservoirs on the ordinary plan cannot be attempted, the violent action of the waste water, in rushing over the waste weir, must in a very few seasons cut away the ground, and leave the reservoir of insufficient capacity Nothing but sound rock will bear the action of the water as it descends to the level of the river again Most promising-looking sites have had to be rejected in consequence of the ground, of which the saddle was composed, proving, on careful and minute examination, to be only masses of loose boulders or rock in a state of such disintegration as to render its rapid removal by the action of the water an absolute certainty

This difficulty led me to consider, some years back, whether it would be possible to construct masonry dams where barriers of rock occurred in the rivers, and adopt some arrangement by which the waste water could be discharged over them, or through them by means of under-sluices With respect to discharging the water over such dams, there is the objection of the great height from which the water must fall, and which, under ordinary circumstances, would cause either the steady destruction of the masonry or the rock at the foot of the dam In order to obtain a reservoir, the efficiency of which would not be impaired at an early date by the accumulation of silt in it, it would be necessary to select some spot where the dam would be of a height sufficient to retain a large proportion of the river's volume, and this height would, in almost every case be so great as to entail the evil I have mentioned, viz, the destruction of the masonry or rock There may be some spots where the configuration of the river bed and sides of the valley will admit of the construction of a dam of sufficient length to reduce the depth of water flowing over the crest, till it becomes so small that it will be all converted into harmless spray before it reaches the foot of the dam As a rule, however, the rivers do not admit of this treatment.

It thus being, as a rule, impossible to pass the waste water *over* the dams, the only alternative was to pass it *through* them by means of under-sluices, and to this point I turned my attention It seemed to me that, if the sluices could be so arranged as to admit of their passing off, without serious hinderance, the whole volume of a river's flood, the silting up of reservoirs would be entirely obviated by keeping the sluices open on such occasions, and that, under such a system, we should be at liberty to form reservoirs of moderate dimensions and cost upon comparatively large rivers, and that though the sluice arrangements must necessarily be expensive, from the strength and durability necessary, and the great power requisite to move the gates under a heavy pressure of water, still the reservoir, by reason of its small size compared to that of the river, must be so often replenished during the year, that it would furnish almost as much water as a larger one constructed on the ordinary plan, and would be very much more valuable than a tank constructed on a tributary stream, because of its source of supply, a large river, being reliable during a season of drought.

The plan also offered the advantage of facility of execution for works on a moderate scale, while at the same time it would in no way interfere with the extension of the works afterwards Thus, instead of having to con-

struct a dam of enormous dimensions with distributing works on a similar scale, which must occupy a long period in execution, and a still longer one for a sufficient development of the irrigation to yield any adequate return on the vast outlay incurred, one of these sluice dams, with its distributing channels, might be quickly constructed for a moderate outlay and thoroughly utilized in a short period, after which, a second dam might be constructed, at some other favorable spot, to increase the supply of water, and thus the system might be extended, as fast as was desirable, without the necessity of sinking a large capital from the very first, and incurring further heavy expenses from the loss of interest, till the irrigation of a large scheme was sufficiently developed.

It had further been observed in the Dekkan rivers, that immediately above a barrier of rock, the slope of the valley was generally very slight for some miles, and that dams in such situations would, up to a certain height, store a large body of water compared to their dimensions.

These advantages were considerable, and would help to cover the cost of the sluice arrangements, which, from their nature, must necessarily be very expensive.

Having thus determined the advantages of sluice dams, I addressed an experienced Engineer in England on the subject of the lifting apparatus and other details of the iron work. By some accident, however, my letter would seem to have miscarried, and I had received no reply, when I had to leave the Dekkan for Sind two years back. On my return to the Dekkan during the present year, however, I was introduced by Lieutenant Carroll, R.E., to his brother, Mr. Carroll, a Civil Engineer of great ability and experience in iron structures and machinery, and I took the opportunity of consulting him on the subject of the sluices. After some correspondence, which on my side was principally confined to the conditions under which the gates would have to be lifted, and on Mr. Carroll's, to the arrangements necessary to meet those conditions, I asked Mr. Carroll if he would be kind enough to prepare drawings to explain the details, which he accordingly did. On the suitability of the plan some further discussion then took place, and this resulted in Mr. Carroll's preparing a fresh series of drawings for sluices on the same general plan as before, but somewhat modified and showing complete details.

These plans are given herewith, with a detailed description and estimate of cost drawn up by Mr. Carroll, and in doing so, I must mention how

valuable an addition they will make to our knowledge and data for the construction of irrigation works in the Dekkan

The case for which Mr Carroll's plans provide, is one in which the river is supposed to be of large size and requiring sluice openings 10 feet square to pass off small trees, &c, which may arrive at the dam during floods The dam is supposed to be 50 feet in height, measured from the sills of the sluices. The power requisite to lift the sluices, under the greatest possible head of water, is about 60 tons * These dimensions and figures are such as will suit most of the Dekkan rivers One of these sluices, under a moderate head of water, would discharge 1,500 cubic feet per second. Fifty of such sluices would therefore discharge 75,000 cubic feet per second, which is nearly equal to the largest flood which has ever been known to occur in the river Moota

The cost of such a dam and sluices for a river as large as the Moota would be as follows —

	Rupees
Masonry dam, ...	4,00,000
Sluices at Rs 50 per square foot, ...	2,50,000
Contingencies and Establishment at 20 per cent,	1,30,000
Total Rupees, ...	7,80,000

In the case of a smaller river, where the obstructions brought down by floods are fewer, and where therefore smaller sluices with less lifting power would answer the purpose, the cost of the plan would be somewhat reduced by the simplification of the sluice arrangements and by the diminution in the weight of the gates, &c. The plans and estimates now given provide for what may be considered a fair average of the requirements of most of the rivers in the Dekkan.

J G. F

POONA, 16*th October*, 1867.

Description of a Design for a Sluice for River Dams. BY E. B. CARROLL, ESQ, C E

This sluice is designed to allow the passage of a portion of the flood water of rivers through high dams, so as to prevent the silting up of the reservoirs they form, and is intended for a depth of 50 feet of water, it

* Including the weight of the gate, &c

requires, therefore, to be of massive construction, and as a number of such sluices would be employed together, they should be as near being absolutely water-tight as possible, or the loss of water under a considerable head would be great, and as the sluice must be opened and closed under the pressure of the full head of water, the working faces, both of the gate and frame, are intended to be covered with brass, and planed true on the surface, and the power of a large screw and capstan is applied to open and shut the gate The sluice opening is 10 feet square, and the mean head of water above it is 45 feet, which gives a pressure upon the gate of $1\frac{1}{4}$ ton per square foot, or a total of 125 tons Taking the maximum frictional resistance of the gate moving in muddy water at two-fifths of the pressure, a power of 50 tons will be required to move it, to which, in opening, must be added the weight of the gate and connections

Gate—The gate consists of a square frame of **U** sections, crossed by three girders of ordinary **H** section, all cast in one piece of tough cast-iron Each girder supports a pressure of about 31 tons distributed, and taking two-fifths of the breaking weight as a safe margin under the statical pressure of water, the girders are proportioned to a breaking weight of 80 tons nearly The spaces between the girders are covered by buckled wrought-iron plates The square frame of the gate is recessed to receive the brass facing, which is made in four pieces, and secured to it by bolts put in from the back

Sluice Frame—The sluice frame consist of two main vertical frames of cast-iron of angle section, 21 feet 9 inches long, forming the sides and the face on which the gate slides, the lower portion of these, for a little more than the length of the gate, is recessed to receive the brass facing, which is made level with the rest of the face, so as to form a continuous surface for the gate to slide on. At the top and bottom of the sluice opening, are two frames, also of cast-iron, which form the top and bottom faces, and are recessed for the brass, these are made with webs curved to suit the top and invert arches of the sluice opening A cast-iron plate across the bottom forms a sill for the gate to rest on when shut Covering plates to keep the gate in place are fixed on the side frames, and extend from the top down to the springing of the arch of the sluice opening, but not lower, so that there may be a clear scour on the face, and no lodgment of silt or other substances can take place to interfere with the movement of the gate, at the same time, in every position the gate may be in, it is held by the

covering plates The side frames are further connected at the top by a cast-iron rib, and the whole sluice frame is secured to the masonry by eight large bolts built into it

Thrust Column and Cap —The power is applied to the gate through a cast-iron column and cap, the cap distributes the pressure, and forms an attachment for the four bolts which distribute the tension, and prevent any portion of the gate being broken or overstrained by the great power applied The column is of circular section inside, with fillets outside, which form flat faces for the guide As the column has to resist some torsional and other strains, it is necessarily stronger than is actually required to take the thrust only, and by a further slight increase of section, is rendered sufficiently strong to take the tensional strain of opening the gate, thus dispensing with special tension rods.

Main Screw Nut and Thrust bearing —The main screw is of hard and stiff wrought-iron or mild steel, 8 inches diameter and $1\frac{1}{2}$ inches pitch The revolution of the capstan with two men at each of the twelve levers, each man exerting 20 lbs on an average leverage of 9 feet, and deducting three-tenths for friction, will give a power at the screw of 66 tons. The screw works in a brass nut attached to the top of the column, and a diaphragm in the column excludes the water, and retains oil about the screw, and by packing the cup at the top of the nut, the water may be practically excluded from the screw when the sluice is open The upward and downward thrust of the screw is borne by four large collars, working against similar brass collars on a brass bush which is confined in a cast-iron casing

Girders —Two wrought-iron girders, firmly secured to the masonry with four holding-down bolts, cross the recess of the sluice, and support the thrust bearing and a platform for the men to work at the capstan

Guide —A guide for the thrust column is fixed to the masonry, this guide is capable of adjustment in the required directions

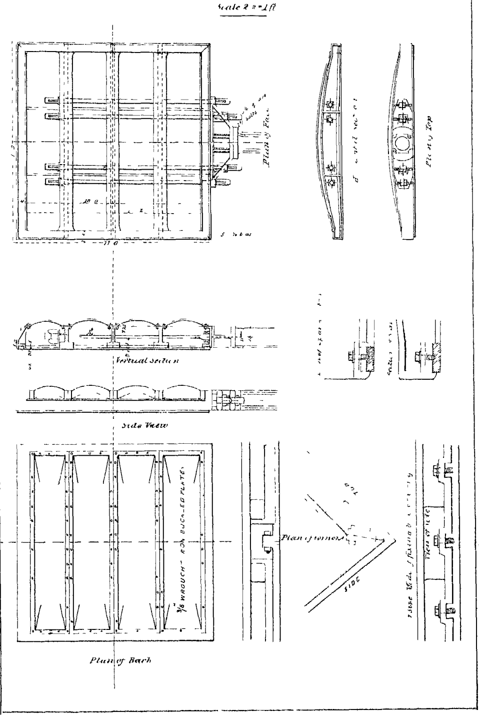
---

Sluice ten feet square for 50 feet head

Specification of Material and Workmanship

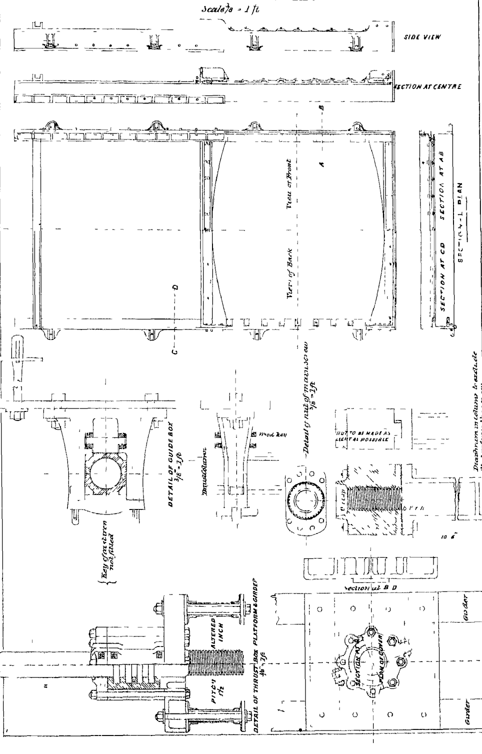
Gate —The gate to be cast of a good tough description of cast-iron, and must be a perfectly sound casting. The brass facings to be of hard brass, these are to be laid in a water-tight cement to prevent the passage of the

IRON SLUICE GATES FOR RESERVOIRS



IRON SLUICE GATES FOR RESERVOIRS.

Scale 3/8 = 1 ft



water behind them, the side facings should be wedged up at the lugs to prevent their slipping. After the brass facings are in their places, the whole must be planed to a true surface. The buckled plates should be laid on cement at the joints to prevent leakage. The four tension bolts are to be made with turned collars where they pass through the shell of the gate, and jammed tight with tapered copper washers bolted under a flange to prevent the penetration of water from the outside.

Sluice Frame.—All the castings of the frame to be of good strong cast-iron and sound castings; they must be firmly bolted together, and the brass facings, after being fixed in the same manner as those in the gate, are to be planed to a true surface, the frame being afterwards taken to pieces.*

Thrust Column and Cap.—The column and cap must be of a very tough description of cast-iron, capable of bearing a considerable tensional strain, the flanges of the column and the top flange of the cap should be planed or turned true.

Main Screw Nut and Thrust Bearing.—The main screw shall be of hard and stiff wrought-iron or mild steel, and is to be turned and finished all over. The nut to be of hard and strong brass, and to be made as tight as possible consistent with strength. The brass of thrust bearing to be made in halves, of a hard and strong description of metal, and as light as possible consistent with strength, to be bored and faced, but not finished on the outside. The cast-iron casing and cover also be made in halves, and a good fit for the brass bush; the cover to be of a very tough description of iron. The capstan head to be secured with three keys to the main screw.

Girders.—Wrought-iron hollow girders, $\frac{3}{4}$-inch thick, top and bottom plate $\frac{3}{8}$-inch web, and $3 \times \frac{1}{2}$-inch angle iron, to be a good quality of girder.

Guide.—The guide to be all of cast-iron, not fitted, the adjustable block at the back to be keyed up with wood keys.

Forgings.—The whole of the forgings, bolts, &c., should be of a good strong quality of wrought-iron.

* The top and bottom brass facings to have bevilled edges to prevent the facings of the gate catching against them.

SLUICE TEN FEET SQUARE FOR 40 FEET HEAD

Table of Weights (*estimated*)

	Cast iron	Brass	Wrought iron	Plates—wrought-iron	Total	Totals			
	lbs	lbs	lbs	lbs	lbs	Tons	cwt	qrs	lbs
Gate, ...	8,710	876	800	1,500	11,886	5	6		14
Cap, ..	1,480		...	...	1,480	.	13		24
Column (2 lengths),	6,680	...	100	...	6,780	3	..	2	4
Guide, ...	2,080		300	...	2,380	1	1	1	
Sluice frame (complete),	10,020	1,055	100	...	11,175	4	19	3	3
Girders, ...	..	...	...	4,655	4,655	2	1	2	7
Main holding down bolts and fixings, ...	850	...	1,880	...	2,730	1	4	1	14
Platform on girders, .	1,580	...	.	..	1,580		14		12
Thrust bearing, ...	1,020	550	190	..	1,760		15	2	24
Capstan head, ...	1,350	.	..	...	1,350	...	12		6
Main screw, ...	.	.	2,840	...	2,840	1	5	1	12
Nut, ...	.	1,000	...	..	1,000		8	3	20
	33,770	3,481	6,210	6,155	49,616	22	3		.

SLUICE TEN FEET SQUARE FOR 50 FEET HEAD

Cost of Metal Work (*estimated*)

English prices

Cast-iron, ..	lbs 33,770	at £ 7	per ton	= £106
Brass, .	„ 3,481	„ 75	„	= „ 116
Wrought-iron forgings, ..	„ 6,210	„ 20	„	= „ 55
Wrought iron plates, ...	„ 6,155	„ 17	„	= „ 47
Turning and fitting up screw and nut,				= „ 40
„ „ thrust bearing capstan, &c,				= „ 40
„ „ column and cap,				= „ 16
Fitting up and planing gate,				= „ 40
„ „ frame,...				= „ 50
„ „ guide, .				= „ 10
Miscellaneous, ...				= „ 30
				£550

AMROLEE, September, 1867

E. B. C

No. CCVII

NOTES ON CARRIAGE

By "Dharwar"

When materials, such as moorum, metal, stone, &c, are carried from a quarry to a work, the time of the agent of transport is occupied in loading and unloading, and in going and returning

The "lead" or distance to which the material is carried is half the length travelled

Let

W, be the weight carried in tons each trip

L, the load, in cubic feet, taken each trip $= \dfrac{\text{weight the agent can carry}}{\text{wt of a c ft of the material}}$

V, the speed of agent in feet per minute—

$= \dfrac{\text{speed in miles per hour} \times 5280}{60} = \text{speed in miles per hour} \times 88$

d, the lead in feet

Z, the time lost in loading and unloading, in minutes.

Y, the time the agent works during the day, in minutes.

N, the number of trips made per day.

M, the time of completing one trip

H, the daily rate of pay, or hire of the agent.

C, the total quantity of material to be transported in cubic feet.

T, " " " in tons.

X, the cost of carrying C to a distance d

k, the ratio of X to H.

The following formulæ express the relations among the above quantities

$$N = \frac{Y}{Z + \frac{2d}{V}}$$

$$M = \frac{Y}{N} = Z + \frac{2d}{V}$$

$$k = \frac{C}{LN} = \frac{CM}{LY} = \frac{C}{LY}\left(Z + \frac{2\,d}{V}\right)$$

$$X = \frac{CH}{LN} = \frac{CMH}{LY} = k\ H$$

The number of cubic feet conveyed a distance d, per day $=$ L N

The numbei of days requned to convey C, to a distance $d = \frac{C}{LN} = k$

The cost of conveymg T tons to a distance $d = \frac{H\ T}{N\ W}$

The cost of one tup, to a distance d, $= \frac{H}{N}$

C and L, oı T and W aıe ın the same units, and repıesent cubic feet or tons , but they may repiesent pounds and hundıed weights, pıovided both are ın the same unit

In the case of caıııage of goods, where, generally speaking, the return tııp has not to be paid foı, ın the above foımula $Z = 0$ and $2d = d$ If $D' =$ the distance the agent will tıavel peı day ın miles,

The cost of caıııage, per ton, peı mile $= \frac{H}{W\ D'}$

APPLICATION OF THE FORMULÆ

Coolies at Ballasting oı Moorumıng with baskets

The speed ıs $2\frac{1}{2}$ miles an houı $\therefore$ $V = 2\ 5 \times 88 = 220.$

The time of emptying and fillıng ıs, say, 1 mınute . $Z = 1$

$$\therefore M = 1 + \frac{2\,d}{220}\quad 1 + \ 0091d$$

Suppose a man to woık steadily for 8 hours, then $Y = 8 \times 60 = 480$

$$\therefore N = \frac{Y}{M} = \frac{480}{1 + \ 0091d}$$

he will carry a load of about half a cubic foot ın each basket

$$\therefore L = \ 5$$

Therefore the nnmber of days one cooly will take to caııy 100 cubic feet, to a distance d (or the number of coolies foı 1 day) equals $k = \frac{100}{480 \times \ 5}(1 + \ 0091d)$, and ıf $h =$ daily rate of coolies hire, the cost $X = k\ h = (\ 4167 + \ 0038d)\ h$

Caıts, at work similar to the above —

Speed $= 1\frac{1}{2}$ miles per hour · $V = 1\ 5 \times 88 = 132.$

Time of loading and emptying about 15 minutes $\therefore$ $Z = 15.$

$$\therefore M = 15 + \frac{2d}{132} = 15 + \ 01515d$$

Suppose a cart to woık steadily 9 houıs, then $Y = 9 \times 60 = 540$

$$\therefore N = \frac{540}{15 + 01515d}$$

The load carried will average 10 cubic feet $\therefore L = 10$.

Therefore the number of days 1 cart (or number of carts 1 day) will take to carry 100 cubic feet, to a distance d, equals $h = \frac{100}{540 \times 10}(15 + 01515d) = 278 + \cdot 00028d$, and the cost $X = (278 + 00028d)H$, if H is the daily rate of hire of carts

To ascertain the distance at which, on the above suppositions, it will be equally expensive to use coolies or carts, we equate the expression for the cost of coolie carriage with that for carts, thus —

$$(4167 + \cdot 0038\, d)\, h = (278 + 00028\, d)\, H.$$

$$\therefore d = \frac{139\, H - 2083\, h}{0019\, h - 00014\, H}$$

And if the ratio of h to H be as 3 to 16, we have

$$d = \frac{3\,198}{00692} = 462 \text{ feet.}$$

This is the distance, short of which, coolies, and beyond which, carts, are the cheaper of the two kinds of carriage.

The same principle might be applied to any other agents of transport—Locomotives, &c

Table I, framed on the above data, gives values of k, for various distances up to $\frac{1}{2}$ a mile for both coolies and carts

Table II, framed on data similar to the above, but chiefly taken from the Appendix to Foord's Notes on Building (Madras), gives also the values of h, or co-efficients of the daily rate of hire, for cartage at leads from $\frac{1}{8}$ of a mile up to 8 miles.

DATA COLLECTED FROM VARIOUS SOURCES

Loads carried by carts at Madras, from Foord's Notes —

Wall bricks, 400, paving bricks, 8 inches square, 200, terrace bricks, 1500, flat tiles, 1000, laterite jelly, broken stone, gravel, 15 to 16 cubic feet, called double loads, but almost invariably put on ordinary carts, slacked chunam, 43 to 46 cubic feet, granite, 6 cubic feet, laterite stone, 9 cubic feet

From a Road Contractor —Load of moorum or gravel, 12 cubic feet, time to fill a cart, 10 minutes, time to empty and yoke cart, 5 minutes, rate of speed of cart, $1\frac{1}{2}$ miles an hour, number of hours per day carts work, 10

From a Road Overseer —$1\frac{1}{2}$-inch quartz metalling, 70 lbs per cubic foot, iron stone do, 93 lbs per cubic foot, moorum or gravel of disintegrated laterite, 80 lbs per cubic foot, sand, 56 lbs per cubic foot, red earth, 48 lbs. per cubic foot, cart load, 16 cubic feet of moorum and 10 cubic feet of metal and iron stone.

TABLE, No I.

Co-efficients, of daily rate of hire, to find cost of CARRIAGE by COOLIES or CARTS, for various distances, framed on data and formulæ given in foregoing notes.

$$X = k\ H.$$

d	Coolies		Carts		*d*	Coolies		Carts	
Lead in feet	N	*k*	N	*k*	Lead in feet	N	*k*	N	*k*
50	330	6	..	.	1,100	43	4 59	18 to 17	586
75	385	7	..	..	1,200	40	4 97	16	614
100	251	8	.	.	1,300	37	5 35	16 to 15	642
150	203	98	..		1,320	37	5 42	15	647
200	170	1 17	..	..	1,400	35	5 74	15	670
250	146	1 37	.		1,600		..	14	726
300	129	1 56	27	362	1,800	.	..	13	782
350	115	1 74	26	376	2,000	..	..	12	838
400	103	1 93	26 to 25	390	2,200	..	..	11	896
450	94	2 12	25	404	2,400	..	..	11 to 10	950
500	86	2 31	24	418	2,600	..	..	10	1 006
550	80	2 51	23	432	2,640	..	..	10	1 017
600	74	2 69	23 to 24	446					
700	65	3 07	21	478					
800	58	3 45	20	502					
900	53	3 83	19	530					
1,000	47	4 21	14	558					

Example of the use of Table —What would be the cost of removing 100 cubic feet of a material, which weighs about 65 lbs the cubic foot, to a distance of 600 feet?

1st. By coolies, if the hire of a coolie be $3\frac{1}{2}$ annas per day.

2nd By carts, if the hire of a cart be $1\frac{1}{4}$ Rs per day

1st. In column for coolies, for $d = 600$, we find, $k = 2{\cdot}69$ $\therefore$ the answer is $2\ 69 \times 3\ 5 = 9\ 415$ annas.

2nd In column for carts, for $d = 600$, we find $k = {\cdot}446$, therefore the answer is $446 \times 20 = 8\ 92$ annas.

TABLE, No II

Co-EFFICIENTS of the daily rate of hire, to find cost of CARTAGE, framed chiefly on data in Foord's Notes

D	N	R	Cost of carrying, ton = kH				Cost of Carrying 100 cubic feet of metal, moorum, &c, X = kH								
			Weight of Load				Cubic feet in Load								
Distance of ' lead in miles	No of trips.	Cost of one trip	8 cwt or 896 lbs	8½ cwt or 952 lbs	9 cwt or 1008 lbs	10 cwt or 1120 lbs	6	7	8	9	10	11	12	15	16
			Values of k				Values of k								
3/16 to ¼	16	0625	156	149	139	125	1 042	893	781	694	625	568	521	417	391
¼ „ 3/8	12	083	208	196	185	167	1 389	1 190	1 042	·926	833	757	694	556	521
3/8 „ ½	10	1	25	·235	222	2	1 667	1 429	1 25	1 111	1 0	909	833	667	625
½ „ ¾	8	125	313	294	278	25	2 083	1 786	1 563	1 389	1 25	1 136	1 042	833	781
¾ „ 1	6	167	417	392	370	333	2 778	2 381	2 083	1 852	1 667	1 515	1 389	1 111	1 042
1 „ 1¼	5	2	5	471	445	4	3 333	2 857	2 5	2 222	2 0	1 818	1 667	1 333	1 25
1¼ „ 1¾	4	25	625	588	556	5	4 167	3 571	3 125	2 778	2 5	2 273	2 083	1 667	1 563
1¾ „ 2¼	3	333	833	784	741	667	5 556	4 762	4 167	3 704	3 333	3 030	2·778	2 222	2 083
2¼ „ 3¼	2	5	1 25	1 176	1 111	1 0	8 333	7 143	6 250	5 556	5 0	4 545	4 167	3 333	3 125
3¼ „ 4½	1½	667	1 67	1 57	1 48	1 33	11 111	9 524	8 333	7 407	6 667	6 061	5 556	4 444	4 167
4½ „ 5¼	1¼	8	2 0	1 88	1 78	1 6	13 333	11 429	10 000	8 889	8 0	7 273	6 667	5 333	5
5¼ „ 8	1	1	2 5	2 35	2 22	2 0	16 667	14 286	12 500	11 111	10 0	9 091	8 333	6 667	6 25

Examples of the use of Table.—*1st*. To find the number of trips a cart will make in a day to a distance of two and a half miles? For D (in col. 1) of $2\frac{1}{2}$ miles, we find the number of trips (in col. 2) to be 3, and by 3rd column, we find the cost of each trip to be ·333 × hire of cart per day.

2nd. To find the cost of conveying 1 ton (or any number of cubic feet weighing a ton) of material, to a distance of $2\frac{1}{2}$ miles, when the cart will take 9 cwt. as a load?

In column 6, opposite distance of $2\frac{1}{2}$ miles, we find k = ·75, therefore cost = k × H = ·741 × hire of cart per day.

3rd. To find the cost of conveying 100 cubic feet of material, to a distance of one mile, when the cart will take as a load 9 cubic feet?

In col. 11, opposite 1 mile distance (in 1st col.), we find k = 1·852, therefore cost = k × H = 1·852 × hire of cart per day.

J. H. E. H.

No CCVIII

IRRIGATION IN SIND.

(2nd Paper)

Memorandum BY COLONEL R STRACHEY, R E, C S I, *Inspector General of Irrigation Works.*

IN the paper which I wrote on the above subject in January 1867, I made certain broad statements as to the character of the existing cultivation in that Province, on the information which I was able to obtain during the short time that my visit to Sind lasted In order to be able to correct any inaccuracy, I asked the Commissioner to be so good as to fill up certain statements relating to the statistics of the agriculture of the province, and having received the most important part of these returns, I think it well to place the facts they contain on record, in an accessible shape, in continuation of my former observations

The first statement made was that cultivation without irrigation hardly had any existence in Sind The returns which I have before me are for the Collectorates of Kurrachee, Hydrabad, Shikarpoor, and the Frontier district, and show the average results of 5 years, from 1861-62 to 1865-66. No returns have been received from the Thurr and Parkur territory, but this is not important These papers then show that, the total cultivation for a year having been 1,539,012 acres, only 72,623 acres were raised without irrigation Of the residue, 1,255,072 acres was irrigated by help of the canals, and 211,317 acres from other sources,—wells, ponds, or direct from rivers I had estimated the canal irrigation at 1,200,000 acres, so that thus far my original statements were as accurate as could have been wished

The next point was the small comparative extent of the rubbee crop,

regarding which I said that it was less than one-tenth of the whole cultivation The actual figures show that this statement is considerably exaggerated when the whole province is taken into account We find that of the 1,539,012 acres of crop, 4,21,450 acres belong to the rubbee and 1,117,562 acres to the khureef, or say $27\frac{1}{2}$ per cent of rubbee and $72\frac{1}{2}$ per cent khureef The distribution of the two crops in the four Collectorates is as follows —

	Rubbee, per cent	Khureef, per cent
Frontier, ...	36	64
Shikarpoor, ...	32	68
Hydrabad, ...	15	85
Kurrachee, ...	35	65

Taking the canal irrigated land alone, which is the most important, we find as follows —

	Rubbee, per cent	Khureef, per cent
Frontier, ...	$8\frac{1}{2}$	$91\frac{1}{2}$
Shikarpoor, ...	23	77
Hydrabad, ...	$9\frac{1}{2}$	$90\frac{1}{2}$
Kurrachee, ...	33	67
Total, .	27	73

Thus it is seen that my assertion was, in fact, true as regards Hydrabad and the Frontier districts, but sensibly in error as regards the other two

I made remarks also as to the generally inferior character of the crops raised, and the predominance of jowar and bajra I regret that I have no figures by which to compare the relative areas of crops of various sorts in the Punjab or North Western Provinces, but the following are the chief figures for Sind.

KHUREEF

	Acres
Jowar and bajra,	6,90,000
Rice,	2,94,000
Cotton,	64,000
Oil seed (til),	40,000
Rest,	21,000
Total,	1,109,000

RUBBEE

Wheat,	183,000
Barley,	31,000
Pulse,	28,000
Oil seed,	32,000
Others,	137,000
Total,	411,000

TWO SEASON CROPS

Sugar,	4,000
Vegetables,	7,000
Fruit trees,	7,000
Total,	18,000

The above details are not very reliable, I fear, but may serve to give some idea of the distribution of the crops

As to the possible extension of cultivation, I said that it would not be unreasonable to expect a total area of 3 millions of acres, and this might be found readily The actual figures show that, including the fallows, there are at present nearly $3\frac{1}{2}$ millions of acres cultivated, and besides these $4\frac{1}{4}$ millions of acres culturable, but not cultivated The suppression of the long fallows would of itself supply the whole area I calculated upon, and there seems no reason to doubt that with a proper allowance of water, one crop yearly could be taken off most of the ground in Sind as in other parts of India

I further expressed an opinion that the existing population of Sind might perhaps be found able to extend the cultivation, if water was provided, from the present $1\frac{1}{2}$ million acres to the 3 millions of acres which I looked forward to I think I must say that further consideration makes me doubtful about this, I see that in the North Western Provinces, a rural population of 27 millions cultivate something more than 27 millions of acres yearly. I fear to expect that $1\frac{1}{3}$ million in Sind should

cultivate 3 million acres, is too much, and that to arrive at any important increase in the area under cultivation in the year, we should have to wait for increased population

The condition of the people in the North Western Provinces however is very different from that of the people in Sind, and I have no other figures that bear on the question, to which I can refer

The following comparison of the main items of the condition of the land, and the population in the North Western Provinces and Sind may be of interest

	North Western Provinces	Sind	Proportion of North Western Provinces to Sind
	Acres	Acres	
Total area, ...	46,323,000	20,689,000	$2\frac{1}{4}$ to 1
Barren,	10 754,000	11,578,000	$\frac{9}{10}$ to 1
Culturable but not cultivated, .	7,401,000	4,238,000	$1\frac{3}{4}$ to 1
Lakhiraj or not paying revenue,	4,121,000	1,428,124	3 to 1
Cultivated, ...	23,747,000	3,436,000	7 to 1
Crop in each year, ...	Probably nearly the whole cultivated area has one crop taken off it each year	1,539,000	15 to 1
Town "	3,050,000	228,000	13 to 1
Rural "	27,060,000	1,350,000	20 to 1
Total population, ...	30,110,000	1,578,000	19 to 1

I will only make the comment on these figures, that it is singular that with such a very large population as is shown to exist in the North Western Provinces, one-fifth of the whole culturable area should be shown as uncultivated It would appear doubtful whether the designation of "culturable" is a suitable one, and probable that much of this land is deliberately kept untilled for grazing purposes If this is not the case, and the land could be cultivated with advantage, it would seem necessary to ask the question, what prevents it?

The general impression left by the data obtained by the last North Western Provinces census is, I think, that, in the best cultivated districts, the average area per individual hardly comes up to one acre, and that the area is rather larger in the poorly cultivated and thinly peopled districts, than in the rich and densely peopled The conclusion seems to be that, under the actual conditions of these provinces, for the proper cultivation of one acre a population of one person is needed.

R S

TABLE I.—Classification of Lands and Crops

		Classification of lands		Frontier of Upper Sind	Shikarpoor	Hydrabad	Kurrachee	Total
A		Total area, . .		(acres.) 1,297,920	(acres.) 4,898,674	(acres.) 5,747,184	(acres.) 8,735,885	(acres.) 20,679,663
A	B	Barren,		101,711	2,365,136	1,988,147	7,123,015	11,578,009
	C	Residue culturable,		1,196,209	2,533,538	3,759,037	1,612,870	9,101,654
C	D	Jagheer, or not paying revenue,		30,519	485,833	572,330	339,142	1,428,124
	E	Culturable not cultivated,		914,804	1,011,615	1,395,684	885,759	4,237,862
	F	Fallows of one year,		117,511	371,658	1,314,337	93,150	1,896,656
	G	Crop of one year	Rubbee, .	37,060	210,928	69,159	104,303	421,450
			Khureef,	66,315	453,504	407,527	190,216	1,117,562
			Total, ..	103,375	664,432	476,686	294,519	1,539,012
G	H	Balance, or not irrigated	Rubbee,	..	1,245	6,630	10,793	18,668
			Khureef, .		9,745	10,753	33,457	53,955
			Total,		10,990	17,383	44,250	72,623
	I	Canal irrigated by lift	Rubbee,		22,769	8,188	7,526	38,483
			Khureef,	48,577	95,979	289,801	45,001	479,358
			Total,	48,577	118,748	297,989	52,527	517,841
		Canal irrigated by flow	Rubbee,	6,035	103,683	34,546	60,124	204,388
			Khureef, .	15,984	322,363	102,813	91,683	532,843
			Total,	22,019	426,046	137,359	151,807	737,231
		Total canal irrigated	Rubbee,	6,035	126,452	42,734	67,650	242,871
			Khureef, .	64,561	418,342	392,614	136,684	1,012,201
			Total,	70,596	541,794	435,348	204,334	1,255,072
	J	Irrigated from other sources	Rubbee, .	31,025	83,231	19,795	25,860	159,911
			Khureef, .	1,754	25,417	4,160	20,075	51,406
			Total,	32,779	108,648	23,955	45,935	211,317
	I & J	Total irrigated	Rubbee, .	37,060	209,683	62,529	93,510	402,782
			Khureef, ..	66,315	443,759	396,774	156,759	1,063,607
			Total,	103,375	653,442	459,303	250,269	1,466,389
Population, .			Town,	20,000	74,143	33,961	100,000	228,104
			Rural, .	60,672	459,476	588,737	240,000	1,348,885
			Total, .	80,672	533,619	622,698	340,000	1,576,989

Abstract of Areas in Acres

	Rubbee	Khureef	Total
Balance, ...	(acres.) 18,668	(acres.) 53,955	(acres.) 72,623
Canal,	242,871	1,012,201	1,255,072
Other irrigation,	159,911	51,406	211,317
Total crop, .	421,450	1,117,562	1,539,012
Fallow, ..			1,896,606
Total cultivated, ..			3,435,668

TABLE II.—Distribution of Chief Crops in Acres

Crop		Frontier	Shikar-poor	Hydera-bad	Kurrachee	Total
		Acres	Acres	Acres	Acres	Acres
Khureef,	Rice, ..	1,433	122,541	65,856	104,556	294,386
	Cotton,	1,506	31,127	27,130	3,797	63,560
	Jowar and bajra,	56,970	287,673	275,181	70,150	689,974
	Til (oil seed),	2,389	9,913	24,021	3,284	39,607
	Others, ..	3,367	6,662	8,718	2,510	21,257
	Total, ..	65,665	457,916	400,906	184,297	1,108,784
Rubbee,	Wheat and barley,	22,984	116,290	29,035	46,412	214,721
	Pulse, .. .	716	19,188	2,657	5,580	28,141
	Oil seeds, ...	11,654	13,427		6,770	31,851
	Others,	1,706	52,338	37,467	45,541	137,052
	Total,	37,060	201,243	69,159	104,303	411,765
Two fusl crops,	Sugar,		892	1,380	2,161	4,433
	Vegetables,	639	2,274	1,295	2,473	6,681
	Fruit trees,	11	2,107	3,946	1,285	7,349
	Total, ..	650	5,273	6,621	5,919	18,463
	Grand Total, ..	103,375	664,432	476,686	294,519	1,539,012

TABLE III.—Weight of Produce in maunds of 82 lbs

Nature of produce	TOTAL		Frontier	Shikar-poor	Hydrabad	Kurrachee
	Area	Weight				
	Acres	Maunds				
Rice, ..	294,000	2,162,000	12,000	1,100,000	500,000	550,000
Cotton, .	64,000	111,000	2,000	50,000	51,000	8,000
Jowar and bajra, .	690,000	6,045,000	1,025,000	2,456,000	2,004,000	560,000
Oil seed, ..	72,000	288,000	70,000	110,000	78,000	30,000
Wheat and barley,	220,000	1,760,000	273,000	313,000	270,000	304,000
Pulse, ..	28,000	168,000	22,000	120,000	10,000	16,000
Others, ..	172,000	1,239,000	42,000	300,000	400,000	497,000
Total, ..	1,540,000	11,773,000	1,446,000	5,049,000	3,313,000	1,965,000
Kurbee or jowar straw, ..	.	24,453,000	4,313,000	8,850,000	9,090,000	2,200,000

TABLE IV.—Distribution of Produce in maunds of 82 lbs

	Rice	Cotton	Oil seeds	Jowar and bajra grain	Wheat and barley	Pulse	Other crops	Total
EXPORTS								
Upper Sind,	2,000	1,000	30,000	313,000	110,000	11,000	17,000	484,000
Shikarpoor,	600,000	14,000	50,000	1,170,000	353,000	60,000	150,000	2,397,000
Hyderabad, .	240,000	22,000	40,000	667,000	90,000	5,000	200,000	1,264,000
Kurrachee,	300,000	4,000	15,000	260,000	100,000	8,000	250,000	937,000
Total, ..	1,142,000	41,000	135,000	2,410,000	653,000	84,000	617,000	5,082,000
KEPT FOR CONSUMPTION								
Upper Sind, ..	10,000	1,000	40,000	712,000	163,000	11,000	25,000	962,000
Shikarpoor,	500,000	36,000	60,000	1,286,000	560,000	60,000	150,000	2,652,000
Hyderabad,	260,000	29,000	38,000	1,337,000	180,000	5,000	200,000	2,049,000
Kurrachee, .	250,000	4,000	15,000	300,000	204,000	8,000	247,000	1,028,000
Total,	1,020,000	70,000	153,000	3,635,000	1,107,000	84,000	622,000	6,691,000

TABLE V.—Areas and population of Talooks on the projected line of Railway from Kotree to Mooltan

Talooks	AREA		POPULATION		
	Total	Crop	Town	Rural	
	Acres	Acres			
Hyderabad, ..	202,000	31,000	34,000	48,000	Length of 120 miles
Halla, .	390,000	36,000	.	49,000	
Shadadpoor, ..	422,000	37,000	..	47,000	
Sukkurund,	797,000	41,000	..	45,000	
Mora, .	685,000	26,000	.	99,000	
Nowshera, .	331,000	66,000	..	59,000	
Kundeara, .	309,000	39,000		26,000	
Roree, .	990,000	19,000	29,000	57,000	Length of 80 miles
Syudpoor, ..	107,000	11,000	..	10,000	
Ghotkee, .	288,000	40,000	..	34,000	
Meerpoor, ..	1,101,000	31,000	.	28,000	
Ooboara, .	288,000	23,000	.	21,000	
Total, ..	5,860,000	100,000	63,000	518,000	
	9,100 sq miles	44 acres per sq m	7 per sq mile	57 per sq mile	

TABLE VI.—Areas and population of districts from Benares to Saharunpore on the line of Railway.

Districts	Total area	Cultivated area	Population	
			Town	Rural
	ACRES	ACRES		
Benares, . ..	637,000	473,000	173,000	620,000
Mirzapoor, ..	3,328,148	1,000,000	82,000	972,000
Allahabad, ...	1,769,567	1,015,000	106,000	1,287,000
Futtehpoor, ...	1,011,426	549,000	25,000	656,000
Cawnpoor, ...	1,514,000	856,000	135,000	1,054,000
Etah, ...	899,000	585,000	60,000	554,000
Etawah, ..	1,044,000	583,000	39,000	587,000
Mynpooree, ...	1,067,000	577,000	42,000	658,000
Agra, ...	1,199,000	868,000	143,000	886,000
Muttra, ...	1,032,000	831,000	74,000	726,000
Allygurh, ...	1,190,000	933,000	122,000	804,000
Boolundshuhur, ..	1,221,000	823,000	111,000	689,000
Meerut, ...	1,512,000	1,082,000	173,000	1,027,000
Mozufternugger, ..	1,054,000	703,000	83,000	599,000
Saharunpore, . ..	1,426,000	1,002,000	123,000	743,000
Total, .	19,003,000	11,910,000	1,491,000	11,862,000
	30,100 sqr miles	396 acres per sqr mile	48 per sqr mile	390 per sqr mile

No CCIX.

SPURS ON THE DAMOODA RIVER.

As used to protect the banks from the action of floods BY LIEUT W SHEPHERD, R.E.

Specification —At an angle of 30° to general alignment of the bank, sál piles are driven 10 to 12 feet into bed of river, 5 feet apart, and in a double row, also 5 feet apart These piles are connected by sál ties across, nailed by large 6-inch spikes, and are connected longitudinally by strong bamboos, as ties, in three places 20 feet of this piling should be 1 foot higher than highest flood, and the piling should be carried inland some 20 feet In continuation of the spur, a small earth bund should be carried back till it reach ground higher than the flood, or to some 100 feet inland. The object of this is to prevent the water, when it rises, from flowing over the crest into the corner made by bank and spur As, up-stream, the water is headed up a couple of feet and advances at a velocity of from 4 to 6 miles an hour, it pours violently into this hollow and gradually cuts the bank away This action proceeds till the earth is cut away from the neck A little protection, say one brick flat would be judicious in this corner. The tops of the remaining piles slope gradually down to the end, where they will be 3 feet above the bed At every 10 feet, a strut down-stream is required

Intermediate to the sál piles, bamboos (from 20 to 24) are driven, also 10 feet deep, these are best put in by fives or sixes—being kept upright by the longitudinal ties. When this network is complete, 3 feet of stone or brick ballast are thrown inside—the top, about the sum-

mer level of river—the bed being excavated if necessary. On the up-stream side, a base of $10\frac{1}{2}$ feet should be given, down-stream, 3 feet base will suffice.

In this network, fascines or bundles of brushwood (of sál twigs for preference) tightly compressed, measuring from 5 to 10 feet in length and 9 inches in thickness, are packed and forced down—cross bamboos laid over will hold these. However much this filling is forced down it will always be found that a great deal of water will pass through.

Groins, 15 feet long, at right angles to the up-stream face of spur made of a single row of sál piles and bamboos, and protected by a stone or brick base at every 100 feet, will stop the scour along the face of the spur.

After the first flood, it will generally be found necessary to pack in two more layers of brushwood.

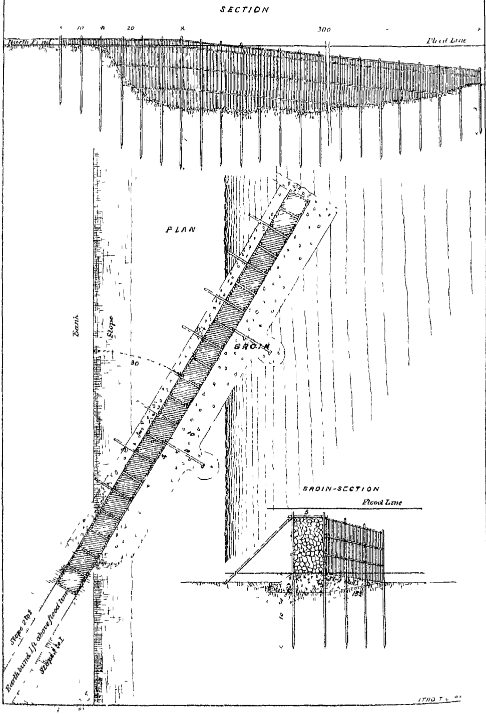
This brushwood spur is rather expensive, costing, on the Damooda, not less than Rs. 9 per *foot complete*, it is, however, strong, and can be quickly made, provided the water be not deeper than 4 feet. It acts well, and is said to protect the bank for a length of six times the perpendicular, where another spur should be introduced if further protection be necessary, but this would only be the case in favorable positions, such as a straight part of the river, with a section rather over the average.

These spurs last a second season with repair, to trust them for a third would be very hazardous.

If they have acted efficiently, they should, in a couple of floods, have caused silt to deposit up to their full height.

W. S.

SPURS ON THE DAMOODA RIVER.



No CCX

EXPERIMENTS ON MORTAR

By Lieut. J L L Morant, *Royal (Madras) Engineers*

The mortar used in the construction of the Masonry Forts in the Bombay Harbour appearing to be capable of improvement, experiments were made to ascertain whether the lime or sand* was in fault, and whether a better mortar at no additional cost could be procured Solely with this object, and with no idea of making the experiments more widely useful, they were unfortunately conducted on a small and limited scale It having, however, been suggested to the writer that a record of these experiments might be useful, he ventures to offer them to the readers of this Journal

During the months of December, January and February 1864-65, twelve kinds of mortar, formed of 2 limes and 2 sands in different proportions, were experimented upon

One lime (that used on the harbour defences) was a poor or impure kunkur (not hydraulic) procured from the island of Salsette Its color after being burnt was a light brown, and it slacked slowly The other lime (also a kunkur) was a rich or fat lime from Surat, in use in Bombay Its color after burning was a pure white, and it slacked readily, giving out much heat

One sand (that used on the harbour defences) was procured from the sea shore of the promontory of Trombay, near the islands of Elephanta, at the top of the harbour It was irregular in size, of a dirty

* Before the experiments were made, the appearance of the sand seemed to show that it might with advantage be changed The lime likewise was thought to require substitution, but this latter idea was proved subsequently to be erroneous.

color, and, though cleansed of its saline* impurities, appeared to contain earthy ones. The other sand (obtained from the Caranjha shoal at the mouth of the harbour) was of a light brown color, clean, hard, even graine and sharp, and appeared to contain many grains of silica and crystals. It had not been cleansed of its saline impurities.

Of the twelve mortars, the first three were formed with the Salsette (poor) lime and the Trombay (impure) sand, and are distinguished by the letter A. The next three, with the Salsette (poor) lime and the Caranjha (superior) sand, and are marked B. The next three, with the Surat (rich) lime and the Trombay (inferior) sand, and are called C. And the last three, with the Surat (rich) lime and Caranjha (superior) sand, and are distinguished by the letter D.

The experiments were conducted on the same plan as that adopted by Colonel Smith, of the Madras Engineers, recorded in Vols. I., II. and IV., of the Madras Corps Papers and were on this wise.

Narrow grooves semicircular in section, $\frac{1}{16}$-inch in diameter, were cut transversely across the centres of two of the best bricks procurable in Bombay. In these grooves, were laid long iron wires ($\frac{1}{16}$-inch) projecting some distance on each side of the bricks. Pairs of bricks were then cemented together groove over groove by the several mortars. The pairs were then numbered and for 10 days kept in a shed open at the sides, and were wetted twice daily with sea water. After that period, they were taken out and left in the open air unwatered.

After the mortars had set for more than a month, their strengths were thus tested. In each pair of bricks, the ends of one of the wires from on each side of the upper brick were bent upwards, and fastened to a hook suspended from a beam. The ends of the other wire in a similar way were bent downwards and attached to another hook on which was hung a scale board. In this scale board, the weights were placed, and weights were added by degrees until the bricks separated. The total weight, including weight of scales, which caused separation, was then registered. After one or two trials it was found that the $\frac{1}{16}$-inch wires were too weak to resist strains of 300 lbs., and upwards. These wires were therefore removed and $\frac{1}{8}$-inch wires inserted in their place. For this purpose, the grooves already formed in the bricks were enlarged by friction, and a semicircular

* The sand was dug up from the sea shore and carried away out of the reach of the tides, and left exposed to the drenching of three monsoons.

groove also rubbed into the adjoining mortar. This accidental circumstance did not, it is believed, make any difference in the experiments.

The mortars were mixed on the same day by twelve picked coolies, and were well beaten up for three hours before being used. On the two following days, the pairs of bricks were cemented together by the same workmen, care being taken that the wires lay directly opposite each other. Before the mortars were applied, the bricks were steeped in water. The consistency of the mortar was rather thick and the joints were $\frac{1}{4}$-inch. Every precaution was taken to insure uniformity in the experiments.

Let us now proceed to examine the results of the experiments (*see* Tables).

First, let us consider the sands. That which is most obviously apparent, is the great effect the quality of the sand has upon the quality of the mortar. The Caranjha sand produces, with both limes, a mortar much superior to that which the Trombay sand produces. In the case of the poor lime, by using the superior sand, the strength of the mortar is increased by *more* than one-half and, in the case of the rich lime, by *nearly* one-half.

We may also notice that both the limes seem to need the sand in a larger or smaller proportion, *varying according to the quality of the sand.* When the inferior sand is mixed with the two limes, the proper proportions of the sand are respectively 1 and $1\frac{1}{2}$. But, when the superior sand is mixed with them, the needful proportions become 2 and 4.

We may thus apparently conclude:

1. That the quality of the sand has a marked effect on the strength of the mortar.

2. That the better the sand, the larger the proportion in which it needs to be mixed with the lime.*

Next, let us consider the limes. The poorer lime when mixed with either sand, appears to give a stronger mortar than the richer lime when mixed with the same sand. The strength of the poor lime mortars are 10.11 and 16.4 lbs., while those of the rich lime mortars are 8.82 and 12.98 lbs. per square inch.

In the poorer lime, the strength of the mortar was diminished by the

* It will be observed that the sands were procured from two parts of the same harbour: one *at the mouth*, the other *at the upper extremity*. The experiments seem to show that, for building purposes, sand at the mouth of a harbour is better than sand higher up. And this would probably be the case in most harbours. The sand at the mouth would be sharp, large and clean. The finer sand, more rounded by attrition and impregnated with earthy and other impurities, would probably be met with at the upper end of the harbour.

addition of sand, while in the richer lime, it was increased by the addition of sand

It may also be observed, that, when the two limes are respectively mixed with the inferior sand, the strengths of their mortars are nearly the same, the poor lime mortar being about $\frac{1}{10}$th better than the rich lime mortar But, when the sand is improved, the poor lime appears to take a greater leap, in producing a better mortar, than the rich lime does, the poor lime mortar being then nearly $\frac{1}{4}$th better than the rich lime mortar We may, perhaps, conclude from this, that the quality of the sand is a more important consideration with the poor, than with the rich, lime

The best mortar appears to be that formed with proper proportions of the poor lime and superior sand, and the worst, that formed with the rich lime and the inferior sand

The Tables appear to give the following proportions of the strength of a square inch of the several mortars

The limes, with the better sand —The rich lime mortar the poor lime mortar 4 5.

With the inferior sand —The rich lime mortar the poor lime mortar 7 8

The sands, with the rich lime —The superior sand mortar the inferior sand mortar 10 7

With the poor lime —The superior sand mortar the inferior sand mortar 10 6

We obtain the following results also from the tables —

	Strength or resistance in lbs avoirdupois
The average strength of the best mortar, ...	16 4
The average strength of the worst class of mortars, .	8 82
The strength of the best mortar between any two bricks, . ..	22 36*

* These strengths, although much larger than those recorded by Colonel Smith, appear much smaller than those obtained by other experimenters Rankine gives the following tables from Vicat and Rondolet

One year after mixture	Tenacity in lbs on square inch	*Six months after mixture*	Tenacity in lbs on square inch
Rich lime,	40	Adhesion of common mortar to brick,	38
Good common mortar,	50		
Bad common mortar,	20		

A comparative table is attached, marked X

Having seen that the quality of the sand produces a marked effect in the strength of the mortar, and it appearing probable that the better the sand, the larger the proportion in which it can be borne in the mortar, let us next enquire what economy is effected by using a lime which bears a large quantity of sand mixed with it, and by using a sand which can with advantage be mixed with the lime in a larger proportion

Let us first take the richer lime and compare the cost of the mortars produced by mixing it in the proper proportions with the two sands It appears to require 4 parts by measure of the superior sand, and only $1\frac{1}{2}$ parts by measure of the inferior one Let us suppose the cost of the lime in powder previous to slacking to be 6 (six) annas a cubic foot, and of the sand to be $\frac{3}{4}$ annas per cubic foot

We then obtain—

	annas annas
Cost of $\frac{10}{3}$* cubic feet of 1st mortar, .. .	$= 6 + 3 = 9$

$\therefore$ cost of 20 cubic feet,† = Rs 3-6

And cost $\frac{5}{3}$ cubic feet of 2nd mortar, ...	$= 6 + \frac{9}{8} = 7\frac{1}{8}$

$\therefore$ cost of 20 cubic feet, = Rs. 5-5-6

Hence *the saving effected in every* 100 *cubic feet of masonry by using with the same lime, a superior sand, is nearly Rs* 2

Let us next take the two limes and compare the cost of the mortar produced by mixing them with the same (superior) sand. The richer lime requires 4 parts by measure of the sand, while the poor lime requires only 2. We then obtain

	annas annas
Cost of $\frac{10}{3}$ cubic feet of first mortar, ..	$= 6 + 3 = 9$

$\therefore$ cost of 20 cubic feet, = Rs 3-6

Cost of 2 cubic feet of 2nd mortar, ...	$= 6 + \frac{3}{2} = 7\frac{1}{2}$

$\therefore$ cost of 20 cubic feet, = Rs 4-11

Hence *the saving effected in every* 100 *cubic feet of masonry by using with the same sand, different lime, is Rs* $1\frac{1}{4}$

The relative prices of the lime and sand vary everywhere, and the extent of the economy affected by using a greater quantity of sand and, consequently, lessening the quantity of lime, depends entirely on their *relative cost* The lime would, at all events, always be dearer than the sand, and it

* In the process of mixing and grinding, mortar is reduced by one third in bulk Hence two-thirds of the quantity of lime and sand is here taken

† It is calculated that in every 100 cubic feet of mortar masonry, there are 20 cubic feet of mortar

pears worthy of consideration, in a general way, that the more sand the rtar can bear *(cæteris paribus)* the cheaper it is

We may thus, it appears, come to the broad conclusion from all that has en said that, *in the cost of mortar as well as in its strength, the quality the sand and lime is of nearly equal importance, and that, as a general le, the stronger the mortar the cheaper it is*

Let us next enquire what may be derived from the experiments regarding the proportionate *co*hesive and *ad*hesive properties of the mortars And re it is first necessary to enter into an explanation of the terms "*co*hesion iled," "*ad*hesion failed," as used in the Table

The *co*hesion of mortar may be defined as its internal tenacity, or as e power it possesses in itself of holding its particles together The *ad*esion of mortar may be said to be its power or property of sticking to the rfaces of the bricks which it unites When the pairs of cemented bricks ere torn asunder, the mortar which had united them was found in some ses to have been itself torn apart, in others, to have entirely separated om the surface of one of the bricks, and in other cases, the mortar was und to be partly itself torn asunder and partly separated from a portion of e surface of one of the bricks The *cohesion* is said to have failed when he mortar showed symtoms of having itself been torn or wrenched asunder, nd the *ADhesion* is said to have failed when the mortar was found to have arted entirely from the surface of the brick It will thus be readily noced that where in any mortar the "*ad*hesion failed" is greater than the *co*hesion failed" the cohesive strength of that mortar is greater than its dhesive strength and *vice versâ*

Let us now proceed in our enquiry

From the Table X, we find with the single exception of Mortar VI which was a very weak mortar and had too much sand), that by increasing he proportionate quantity of sand, the adhesive property of the mortars as increased and the cohesive property proportionately diminished, that he increase was not however strongly marked, and that, in all the morars, their cohesive power was greater (but not by very much) than their dhesive power

Taking each of the mortars in detail, we obtain the following results —

Five of the twelve descriptions of mortar give very variable results, and hese five mortars (II, III, VI, IX, and X) are those which possess the east strength of all the mortars except one

In four other mortars, the strongest specimens possess the greatest proportionate adhesive strength, and these four (V, VIII, XI, XII,) mortars, are those which have the greatest strength of all except one. And lastly, in the strongest specimens of the three remaining mortars, the adhesive and cohesive properties are equally divided, and of these three mortars, (I, IV, VII,) one was the best of all, one the third best, and the last the least strong of all.

There is only one other subject on which these experiments throw any light, viz., on the enquiry whether mortars increase in strength after the first month the longer they are exposed to the air. The abstract Table (Table Y) which has been prepared, would seem to show that they do not do so.

In conclusion, it need only be said that the following branches of enquiry might have received attention, and it is to be regretted that they did not do so—

1. The effect of using sea water in the mixing and moistening of the mortar.

2. The effect of cleansing the sand of its saline impurities.

3. The rate at which the mortar becomes carbonated by the air.

4. The strengths of mortars subjected to a force applied in the same direction as the plane of its surface, *i. e.*, to *torsion*. This enquiry would be particularly suited to Harbour Defence Works.

TABLE X

SHOWING the results of experiments on twelve kinds of mortar formed of two limes and two sands mixed in different proportions, the trials having been made by tearing joints of bricks asunder The lime has been estimated in powder previous to slaking

[*The strengths are in lbs and decimals of a lb*]

No of the mortar	Average strength or resistance of mortar per square inch in lbs. avoirdupois	Maximum and minimum strengths or resistances of mortar per square inch in lbs avoirdupois		Average strength or resistance of mortar between two bricks in lbs avoirdupois	Proportionate failure of cohesion and adhesion in decimals Cohesion internal tenacity of mortar Adhesion its power of sticking to the bricks		Class and composition of mortar Lime and sand mixed by measure	Average length of time mortars were allowed to set in days	Number of experiments	Remarks
					Cohesion failed	Adhesion failed				
I.	10 14	18 70	7 28	416 7	308	692	A Lime 1, sand 1	49½	10	A mortars—Poor lime and bad sand
II	8 98	17 31	5 89	366 7	4735	5265	A Lime 1, sand 1½	47	9	
III.	9·01	18 63	4 43	371 00	475	525	A Lime 1, sand 2	31 2	10	
IV.	16 4	20 43	10 03	669 2	4542	5458	B Lime 1, sand 2	45 7	10	B mortars—Poor lime and good sand
V	8 58	15 06	4 9	351 5	4954	5046	B Lime 1, sand 3	54 6	9	
VI	4 67	7 18	3 15	191 6	2417	7583	B Lime 1, sand 4	52 8	10	
VII	4 14	6 16	2 97	170 4	3075	6925	C Lime 1, sand 1	37 2	10	C mortars—Rich lime and bad sand
VIII	8 82	16 5	5 45	362 545	4356	5644	C Lime 1, sand 1½	49	11	
IX.	6 8	10 4	4 8	278	4896	5104	C Lime 1, sand 2	42	8	
X.	11 29	18 17	7 26	465 36	4243	5757	D Lime 1, sand 1	47	11	D mortars—Rich lime and good sand
XI	11 75	22 36	5 9	481 1	4916	5084	D Lime 1, sand 2	51 6	10	
XII	12 98	15 23	10 6	529 3	5928	4072	D Lime 1, sand 4	48 8	10	

TABLE Y

SHOWING the strengths of the mortars and the lengths of their setting periods The mortars being all different, the comparison of their strengths should be made separately for each mortar

[*The strengths are in lbs and decimals of a lb*]

No. of the mortars	Length of time the mortars were allowed to set, in days																				Remarks
	days 32	days 33	days 34	days 35	days 36	days 37	days 39	days 40	days 42	days 47	days 48	days 53	days 54	days 55	days 56	days 57	days 58	days 59	days 60	days 62	
	Average strengths of mortars in lbs Avoirdupois per square inch																				
	lbs	lbs	lbs	lbs.	lbs	lbs	lbs	lbs	lbs	lbs.	lbs	lbs	lbs	lbs.	lbs.	lbs	lbs	lbs.	lbs	lbs	
I	..						8 38		11 7	7 5		7 7								14 4	
II		..				9 00	6 4													10 2	Poor lime and bad sand
III	16 45		..		5 45				18 6											11 00	
IV		..		16 97										..		12 96		18 2	16 6		
V		13 3			..												6 3	9 5			Poor lime and good sand
VI				3 26									..	..			4 4	5 5			
VII.			..	4 2											-	3 8					
VIII			.	8 2									16 46	..	8 3	7 3					Rich lime and bad sand
IX	.		5 4	8 35		.									5 2		7 9				
X.	13 4		..	..			..									10 00				..	
XI.											10 00		11 05	13 00			..				Rich lime and good sand
XII.								12 75	..		11 88		14 1		12 7						

TABLE Z

COMPARING results of experiments made in India on the strengths of mortars The resistances are the average of many trials and are given in lbs avoirdupois per square inch, the trials having been made by tearing joints as under Lime and sand mixed by measure

[*The resistances in lbs and decimals of a lb*]

Nature of the lime or cement.		Number of trials	Age of mortar	Composition of mortar lime estimated in powder previous to slaking — For one part of lime cement or powder: 1 sand	1½ sand	2 sand	3 sand	4 sand	Proportionate failure of adhesion and cohesion: Cohesion	Adhesion	Depth of the bond of mortar joint carbonated by the air in inches	Name of experimenter, &c
Madras shell lime,	Worked up with plain water,	16	1 month			1.56			15	85	0.625	Captain Smith, Madras Engineers
Do,	Worked up with fresh lime water	4	„	.	.	1.5			5	5	0.5	
Do	Worked up with fresh lime water containing ¼ lb of jhaggery to each gallon,	5	„			2.328			1.00	0.00	0.383	
Do,	Worked up with fresh lime water containing ½ lb of jhaggery to each gallon of water,	5	„			3.48			1.00	0.00	0.362	
Do,	Worked up with fresh lime water containing 1 lb jhaggery to each gallon water,	10	„			3.62			875	125	0.23	

Do,	Worked up with fresh lime water containing 2 ℔ of jhaghery to each gallon of water,	12	„	•		4 84	•	•	917	083	0 156	Capt Smith, Madras Engineers
Do,	Worked up with plain water,	10	„		3 72				9	1	0 31	
Do,	Worked up with lime water containing 1 ℔ of jhagghery to each gallon,	10	„		5 77		•	•	1 00	0·00	0 125	
Do,	Worked up with plain water,	5	3 years		4 00				53	47	The whole joint	
Do,	Worked up with lime water containing 1 ℔ of jhagghery to each gallon,	5	„	•	5 00				52	48	„	
Do,	Do do,	20	13 years		6 08		•		475	524	„	
Do,	Worked up with spring water,	9	„		4 2	•			324	676	„	
Do,	Do do rain water,	12	„		4 72				426	574	„	
			days									
Bombay kunkur lime (poor),		10	49½	10 14			8 58		308	692		Lieutenant Morant, R E
Do	do,	9	47		8 98				473	527		
Do	do,	10	31 2			9 01	•	4 67	475	525		
Do	do sand changed,	10	45 7			16 4			454	546		
Do	do do,	9	54 6		•		•	••	495	505		
Do	do do,	10	52 8						241	759		
Do	do (rich),	10	37 2	4 14					307	693		
Do	do,	11	49 00		8 82				435	565		
Do	do,	8	42 00			6 8			48	52		
Do	do sand changed,	11	47 00	11 29					424	576		
Do	do do,	10	51 6			11 75			491	509		
Do	do do,	10	48 8	•	•			12 98	593	407	•	

The surfaces of the bricks in Captain Smith s experiments were rubbed smooth before the mortar was applied to them
The surfaces of the bricks in Lieutenant Morant s experiments were left untouched

No. CCXI.

DISTRIBUTION OF CANAL WATER.

(2nd Paper.)

THE following illustration will explain the scheme proposed in a former paper* on this subject.

Supposing AB, *Fig* 1, to represent six or seven miles of rajbuha channel in moderate digging, the irrigators being allowed to put in their colabahs wherever they pleased, "kuls" at intervals (*vide* dotted lines in sketch) would represent the ordinary arrangement.

In place of this, it is proposed to collect the outlets at the most suitable points on the rajbuha, and to station chokeedars at such places to measure the quantity supplied to each irrigator, so that payment by quantity may be substituted for payment by area irrigated. In many cases the "kuls" will be longer, and it may sometimes be necessary to run them through the lands of many villages, but it is assumed that these objections are more than counter-balanced by the advantages arising from the centralization of the irrigation. Taking the former figure, we should have something like the sketch, *Fig* 2, the outlets being collected at the point C.

The fluctuations in the supply render any attempt to gauge the quantity run out by each "colabah" almost hopeless. *This can be easily remedied* by maintaining full supply depth (by bunding, if necessary), at the points where the outlets are grouped.

For instance, in Chokee No. I (*vide Fig* 3) there may be only 3 feet of water, but we can head up by kurries or sleepers till we obtain a depth of 4 feet of water. Four feet is fixed upon for the following reasons:—

1. The usual depths being 3 feet, 4 feet must command all existing "Tor" irrigation, and it permits also of a clear fall from distributing head into "kul," and the head of water will therefore be constant for all outlets.

2. The depth of water in our rajbuhas seldom or never exceeds 4 feet,

* *See* No. CLXVII of these Papers.

even with an extraordinary supply,—so that the head of water will never be greater than that due to 4 feet

This enables us to place all the outlets at a fixed depth below full supply line (4 feet above bed)

In *Fig* 3, the values of x, y, and z are ever varying, but outlets just above the weirs will always have a constant head of water. The silt deposits caused by the damming up will not usually interfere with the discharge at the head, as rajbuhas generally have to run many miles before free flow irrigation is possible In *Fig* 3, the first weir is placed just below the 6th mile

With such an arrangement, the chokeedar has really only to keep a "Time Table," but to give him some work, other records may be kept up, from which, data for future projects may be extracted Besides, such information might be collected in the different chokees, as would enable an inspecting officer to decide all disputes and claims on the spot An intelligent chokeedar could also, after a little practice, estimate pretty near the mark, the quantity he would require in a given period beforehand An Executive Engineer, with such estimates in his hands from all parts of his division, could regulate the supply in every channel, so that a drop of water need not be thrown away, while there was any demand

Illustration —Below will be found a Tabular Statement of the irrigation of the Laddeki Bhoollar Chokee, showing the difference between the present and the system *proposed*

Fig 4 shows the present distribution of the colabahs in this chokee, *Fig* 5 a distributing head which it is proposed to substitute for the isolated outlets

The "Dal" irrigation will be considered hereafter

Name of village	Tor Irrigation (Left bank)						
				New System			
	No of shareholders	No of shares	No of colabahs at present	No of outlets.	No of do taken up	Nominal area irrigated in acres	Probable expenditure of water per second
L Bhoollar,	15	10	17	1	6	200	
Pandowke,	12	10		2		200	
L Bhoollar, ..	9	7		3		110	
Asal Salema,	6	8		1		160	
Pandowke, .	10	9		5		180	
Pandowke, ...	19	9		6		180	
Total, ..	71	53				1 060	

Name of village	FOR IRRIGATION (Right bank)						
				NEW SYSTEM			
	No of Share-holders	No of Shares.	No of colabahs at present.	No of outlets	No of do. taken up	Nominal areas irriga-ted in acres.	Probable ex-penditure of water per second
L Bhoollar,	2	3	5	7	4	60	
Asal Salema,	5	4		8		80	
L Bhoollar, ...	9	7		9		140	
Asal Salema, .	8	5		10		100	
Total,	24	19				380	

There are twelve outlets provided, (six on each bank), each outlet is supposed to irrigate 200 acres In each outlet there are 10 shares, so that one share will represent the right to irrigate 20 acres, and the right to use an outlet for 5 years can be purchased for Rs 25, or one share for Rs 2-8-0 It will be seen, from this Table, that 72 out of 120 shares and 10 out of 12 outlets are taken up by the existing irrigation, only two outlets and 48 shares being left to accommodate future irrigators The most suitable site for the distributing head is shown by the dotted square in *Fig* 4

The time can be measured by a double clepsydra (*Fig* 6), the water falling in the upper and rising in the lower cone It should be constructed so as to run for 24 hours, and, when X is emptied, Y can be put in its place, and X put in Y's place Given the depth in upper, to calculate depth of water in lower, cone, would puzzle a chokeedar, and if he made a guess at it, he could scarcely escape detection.

The following forms will probably demonstrate the simplicity of the scheme much better than any amount of verbal explanation.

Abstract of work to be done by Revenue Establishment—*With a constant head of water*

Chokeedar's Return, 23rd June, 1868 Rajbuha Chokee No 2. Outlet No 5

Name of irrigator	Time *		Difference	Signature or seal	Remarks
	Opened	Shut.			
Abdoolla, ...	9	61	52		
Sawan Sing, . .	30	36	6		
Sant Sing, ...	30	48	18		

* The day is divided into 100 parts, *vide* page 404, Vol IV.

The following is a page from one of the revenue books, supposed to be kept in the Executive Engineer's Office for each rajbuha.

Chokee No 2 Outlet No 5. Year 1868

Month	Date	Abdoolla		Sawan Sing		Sant Sing		
		Time	Cubic feet in thousands	Time	Cubic feet in thousands	Time	Cubic feet in thousands	
June	15th	52	120	6	13 85	18	41 54	
	25th			30	69 25	26	60 00	&c , &c

If it is not thought advisable to interfere with the flow of the water by damming up, the chokeedar's return may be in the form given at page 403, of Vol IV, and the revenue books in office ruled up as follows —

Chokee No Outlet No Year

Month	Date	Abdoolla			Sawan Sing			Sant Sing			
		Mean head of water	Time	Cubic feet in thousands	Mean head of water	Time	Cubic feet in thousands	Mean head of water	Time	Cubic feet in thousands	
June	15th	1 00	52	120 00	1 5	6	18 70	1 5	18	56 10	
	20th			.	2 0	30	130 00	2 0	26	112 67	&c , &c

June, 1868. E S

No CCXII.

ENGINEER AND ARTILLERY DESPATCHES, ABYSSINIAN FIELD FORCE.

[ABRIDGED]

From LIEUT-COLONEL ST CLAIR WILKINS, R E, *Commanding Engineer, Abyssinian Expeditionary Force, to* CAPTAIN T J HOLLAND, *Assistant Quarter Master General*

Zoulla, May 30th, 1868

SIR,—I have the honor to submit, for the information of His Excellency Lieut-General Sir Robert Napier, G C B and G C S I, Commander-in-Chief, Abyssinian Expeditionary Force, a brief report of the operations of the Engineer Department in Abyssinia, and of the services of the officers of the departments, together with a report in detail of the several works executed

The officers of the reconnoitring party, despatched from Bombay on the 16th of September last year, having, on the 2nd of October, examined the port of Massowah and the water-supply of that port on the plains of Mucculloa, five miles distant from the sea, formed the opinion that that harbour was too small to accommodate more than half-a-dozen vessels, and that the water-supply was of too limited and precarious a nature to meet the requirements of the Expedition The *Euphrates* and the *Coromandel*, containing the exploring force, then steamed southwards into Annesley Bay, and the water-supply at Negoosa, on the promontory of Buri, was examined without satisfactory results Crossing the bay, the vessels took up a position off the village of Zoulla, and the water-supply from the Huddas River promising fairly, and an investigation of the shores round

the bay, combined with information obtained, presenting no better prospect, it was determined to make Zoulla the base of exploration of the country

Piers —The beach at Zoulla shelving very gradually into the sea, it became at once a matter of great importance to commence the construction of a suitable pier for landing purposes Some iron girders and stout rafters had been brought up in the steamers to assist in forming a pier, but from the nature and formation of the shore, it was evident that a long pier would have to be constructed from local resources The plain bounding the sea was covered with low bushes, but unfortunately no stone was to be had, under these circumstances, fascines were prepared from the brushwood, and being strongly staked down, formed retaining fences for the filling in.

Arrangements were at once made for the collection of native craft from Massowah and the neighbouring ports, and the conveyance of stone from the opposite site of the bay commenced towards the middle of October. Sea-walls were then built outside the fascines, and by degrees the pier was run out 900 feet into the sea, giving a depth of 5 feet at low water springs. The greater portion of the pier was filled with stone. This stone pier was completed sufficiently to be used in landing the advance brigade and their horses in November, and by the middle of December, the pier was in general use, having a tramway laid from its head to some distance up the beach, thus greatly facilitating the landing of Commissariat, Land Transport Train, Ordnance, and other stores A tramway was laid down on the beach, running down to low water line, as early as October, and was of much service previous to the pier coming into use

In this month also a road, 50 feet in breadth, was cleared through the jungle from the pier to the camp, $1\frac{1}{4}$ miles distant

By the end of November, the works executed at Zoulla comprised the nearly finished stone pier, a cleared road to camp from the sea, the clearing out of the old village wells in the bed of the Huddas River, and the construction of twenty new ones, whereby about 2,000 men and 2,000 animals were watered daily, a large store shed, and a water-shoot, 480 feet in length, raised on trestles above the sea, for conveying to the tanks, which were being collected on shore, sweet water condensed by Her Majesty's ship *Satellite*

The satisfactory progress made with the Zoulla works generally up to the close of the year, is attributable to the untiring zeal and energy displayed by the officer in executive charge, Captain W. W. Goodfellow, Field

Engineer, and Second in Command of Royal Engineers with the force. It is unnecessary for me to bring this officer's subsequent services to His Excellency's notice, those services having been performed under His Excellency's own observation I would wish, however, to record how highly I appreciate Captain W W Goodfellow's services, and how much I feel indebted to him for his support and example, and for the cheerfulness and fertility of resource he has so constantly displayed

On His Excellency's arrival at Zoulla early in January, many additional Commissariat and other sheds had been erected, and the commencement made of a second pier—a pile pier—the materials for which had been prepared and sent out from Bombay Captain Chrystie, R E, Field Engineer, assumed charge of the Zoulla works on the 1st of January, and in his hands the pile pier made rapid progress, and was nearly completed up to the island by the 5th of February, when Captain Chrystie was ordered to Senafé, and was relieved at Zoulla by Captain Wood, R E, Field Engineer

Captain Wood completed the pile pier, and built a new head to the stone pier, greatly improving it Captain Wood's work was distinguished by its solidity and permanent character That the piers were not damaged by the late gales is attributable to this officer's good work at the head of the piers Captain Wood was unfortunately taken ill, and had to go on board the hospital-ship, Lieutenant Lee, Royal Engineers, Assistant Field Engineer, assuming charge of the Zoulla works I have much pleasure in testifying to the excellent character of the works carried out by this officer, who has had many years' experience on public works

Lieutenant Lee completed the works at Zoulla as they now stand

Railway—A tramway having been proposed to be laid on the lowland country between Zoulla and the base of the mountains at Koomeylee, a distance of about twelve miles, Lieutenant Willans, Royal Engineers, Assistant Field Engineer, commenced surveying the line in November, and the works were commenced in December, when the ships with the plant from Bombay began to arrive.

An iron girder bridge, of three spans of 20 feet, was constructed over a branch of the Huddas River in December, and about a mile of earthworks were constructed and rails laid by the end of January

Six miles of railway, with a branch of half a mile to the Commissariat sheds, were completed by the 19th February, and the Commissariat De-

partment commenced running all their stores and provisions to the 6th-mile siding. This enabled the Land Transport Train to move the whole of their animals from Zoulla, thus relieving the water-condensing operations enormously, and saving considerably, in time and animals, in the trip from the coast to Senafe. All Commissariat and other stores, now sent out to the 6th-mile siding were conveyed away by carts and baggage-animals sent out from Koomeylee, and which returned to that post the same day.

A second Commissariat siding was opened for traffic at the 9th-mile from Zoulla on the 28th of March, thus further reducing the labor of the transport animals.

By the end of April, the railway was completed to within a mile of the camp at Koomeylee. The traffic on the line had now become so great that the Commissariat Department absorbed the whole of the rolling stock. It was found that, what with the Commissariat requirements and the increased time taken up by the lengthened journey, trains for the conveyance of railway plant could no longer be given. With extreme reluctance, it was then decided that the works must be brought to a close by the construction of a loop-line and terminus at about a mile from Koomeylee.

The heat on the plains was so great when the works were being closed, that not more than five and a-half to six hours' work could be obtained from the workpeople.

By great good fortune, water was obtained from wells at the 4th, 7th, and 9th miles on the road, by the excavation of wells 50, 65, and 85 feet in depth respectively at the points named. Watering-tanks for the engines were set up by the side of the line, and fed from these wells by piping.

A good supply of water being obtainable at the 4th mile, "Pioneer Wells," the locomotive workshops were established at this place. It was also found desirable that the whole of the locomotive establishment should be permanently situated at the "Pioneer Wells," so as to be close to their works.

The railway, properly-speaking, is only a tramroad, so far as the rails and rolling-stock are concerned. The rails are light, and the rolling-stock consists of contractor's engines and trucks. Nevertheless the tramroad has been called upon to do the duty of a railway, and it has, by constant care and management, been kept up to the work required of it.

The main line, from Zoulla to Koomeylee, is $10\frac{1}{2}$ miles in length, and

altogether, 12 miles 106 yards of rails have been laid. For the first 6 miles, the plain rises pretty gradually from the sea to a height of about 100 feet above that level. The railway line then passes through a low range of hills, keeping the bank of the river; there is some heavy work on this portion of the line in cutting, embankments, and bridges. The line then descends about 50 feet into the Koomeylee plain, and rises to a height of 348 feet at the Koomeylee terminus.

Eight iron girder bridges and a large number of drains have been constructed on the line.

The whole of the railway,—earthworks, embankments, cuttings, bridges, and drains,—have been executed by troops of the force and by men of the Army Works Corps. A few civilian plate-layers, some from Bombay, and some obtained from the shipping and departments of the Army, have superintended the plate-laying. The greater portion of the railway has been constructed by the 23rd Punjab Pioneers, commanded by Major Chamberlain, and the 2nd Bombay Grenadiers under Lieutenant Colonel Muter. I am particularly desirous that the services of these two corps, in performing a duty so utterly new to them, should be brought to His Excellency's notice. The cheerfulness and willingness on the works of the men of these corps, inspired by the spirit and tone of their officers, have been most conspicuous, and is deserving of the highest praise. The Punjab Pioneers are very clever, and quite artistic in all they do under the guidance of their skilful commander. The wells made by them, at the station called "Pioneers' Wells" and at the bridge, are models of skill in well-digging.

The 2nd Grenadiers worked on the line during the hot season, and always evinced the greatest alacrity and desire to further the work.

I respectfully wish to bring to His Excellency's special notice the services of Captain Darrah, R.E., Field Engineer, who has superintended the railway works from the commencement to the completion, as well as the services of his assistants, Lieutenant Willans, R.E., Lieutenant Pennefather, R.E., Lieutenant Band, R.E., Lieutenant Graham, 108th Regiment, Assistant Field Engineers.

As the railway works have been carried out under my own supervision, I am able to speak from personal observation of the devotion to duty displayed by the above officers. Early and late, day by day, for upwards of five months, have these officers, under most trying circumstances of cli-

mate, strained to the utmost ability and strength, to further the success of the expedition so far as the railway was concerned.

His Excellency should also be informed of the exemplary conduct throughout of the under-mentioned non-commissioned officers employed on the railway works from nearly their commencement to the completion. All skilled men, the value of their services has been increased by their good conduct.—Corporal Heinig, R.E., 10th Company, Sergeant Webb, Corporal Recks, Private Cooper, Private Cox, 1st Battalion, 4th Regiment, Private Miller, 45th Foot.

The difficulties of even trusting a railway with unprofessional labor have been greatly enhanced from the circumstances of five different descriptions of rails having been provided for the work, on four different principles of fixing. Had it been possible to land and carefully stack each description of rail prior to plate-laying, the variation in the rails would not have been the cause of much inconvenience. As it happened, this difference of pattern proved most annoying, for the disembarkation of the plant just kept pace with the requirements of the works, and the line was fed from hand to mouth throughout, consequently there was no time for sorting and stacking. The Kurrachee rails have given the greatest trouble in laying and maintenance, being very much worn and bent, and being a joint chair, and not a fish-plated rail. The 40-lb. fish-plated rails would have been more useful if the fish-plate holes had fitted those in the rails. In five cases out of ten they did not fit, nor would the bolts go through the holes.

My opinion is that railways required for the operations of war should be carried out entirely as a civil work by engineers and contractors who make it their business to construct railways, and who would bring to bear on the works their own experience and that of professional establishments.

In the present case it is worthy of remark, as a set-off, that, although the railway works have not been constructed so well and so quickly as they would have been by a professional contractor, yet the line was made in time to be exceedingly useful, and the difference of expense between the two systems is very great. I understand the tender of an eminent contractor for making the Abyssinian railway was at the rate of £6,000 a mile, which would have brought up the cost of the whole line to about £72,000, exclusive of rails and plant. As near as I can ascertain, the cost of making the Abyssinian railway has been about £6,000 altogether, exclusive of rails

and plant It must not be supposed from this statement that the contractor (had the line been let to him) would have made a large profit His expenses would have been very great for labor and superintendence

Roads—Early in November last year, when it was determined to explore the Koomeylee Pass, No 1 Company of Bombay Sappers were sent to work in the Sooroo defile under Lieutenant Jopp, R E, Assistant Field Engineer From the time of the Koomeylee Pass being adopted as a route, strenuous exertions were made to construct a cart road through the Sooroo defile, the road was completed by the 31st January, the works having been well carried out under the directions of Lieutenant A K Jopp, R E, Lieutenant (now Captain) Stuit, R E, and Lieutenant Coaker, R.E, who are deserving of His Excellency's notice The Sooroo defile occupied the labor of two companies of Sappers and two companies of Beloochees for three months The road, when completed, had a breadth of about 10 feet, and was constructed on the principle of ramping over boulders and obstacles, instead of attempting their removal by blasting The boulders which it was necessary to remove with the miner's drill, were found to be of the toughest description of granite, and for some time the Sappers were unable to make any impression upon them

Almost simultaneously with the construction of the Sooroo defile road, the work of clearing a cart-road the whole way from Zoulla to Senafé, a distance of 63 miles, was taken in hand. The rise in this road, in the length of 63 miles, is 7,400 feet About a mile of defile road at Rayray-guddy had to be built much in the same manner as the Sooroo, and at 1½ miles from Senafé, a ghaut road, 1½ miles in length, had to be cut out of the mountain side The whole road was open for cart traffic the early days of February The road has been kept in a perfect state of repair up to the 8th of May, when thunder-storms commenced breaking over the passes and doing serious damage to the made road.

A cart-road was also made between Senafé and Addigerat, a further distance of 17 miles Two pieces of ghaut-road occur on this line, the Goon Goona and Keisuba Ghauts from Addigerat to Antalo, so much of the route was cleared as to render it possible for the 9-14th Battery to be driven to that post

Beyond Antalo to Magdala, the road can only be described as a track passable for laden mules and elephants

An alternative route was commenced by the Huddas River, but was

abandoned thiough the sickness of the troops engaged and fiom other causes Captain Hills, R E , Field Engineei, who held the post of Executive Engineei at Koomeylee and Senafé duiing the campaign, has exeited himself in a veiy cieditable manner in exploiing for the best line of road to be taken to the Huddas

Watei-supply —When laige bodies of tioops and followeis had landed at Zoulla, and animals of the Tiansport Tiain accumulated in gieat numbeis, it became necessaiy to condense a laige supply of watei About 200 tons of water weie landed daily fiom steameis in the haiboui by means of a wooden shoot which conveyed the watei to iion tanks, from which a long wooden tiough was kept constantly filled The tioops soon moved up-countiy, and on the opening of the sixth-mile siding on the iailway, the whole of the Tiansport Tiain animals weie moved to Koomeylee, then the supply requiied fiom the condensers became greatly ieduced.

The allowance of watei to eveiy individual in Zoulla camp—officers, soldieis, and followeis—has been $1\frac{1}{2}$ gallons daily per head, a by no means wasteful allowance when the climate is consideied

A water-supply for about 5,000 animals and pioportion of men was provided at Koomeylee in Decembei and Januaiy, but on these numbers being gieatly increased in Maich, it became necessaiy to inciease this supply Foice, suction, and chain pumps weie set up at the wells, capable of wateiing 10,000 to 15,000 animals and 5,000 men, and long ranges of troughs weie piovided, iendeiing the wateiing of animals an easy operation

Lieutenant Le Mesurier, R E , Assistant Field Engineer, came out from England specially to set up the new American Tube * wells and pumps at the diffeient posts This eneigetic officei took charge of the whole watei-supply generally, and, with his assistants, inaugurated and carried out a very efficient system of watei-supply at each post as far Addigerat. Lieutenant Le Mesuriei's creditable exeitions have doubtless come under His Excellency's own obseivation, it only iemains, therefore, for me to bring to His Excellency's favoiable notice the services of that officei's assistants—Lieutenant Claik, R E , Lieutenant Sargeaunt, R E , Lieutenant Protheioe, M.S C , Lieutenant Manwaiing, R E , Assistant Field Engineers

* *See* No CXCVI of these Papers

Lieutenant Le Mesurier has favoured me with the following remarks upon the water-supply between Addigerat and Magdala —

Beyond Addigerat no stores could be carried, and paved slopes were made into the nullahs for the animals, Norton's tube wells supplying drinking water

Beyond Antalo, four Norton's tubes and driving apparatus complete were carried on six mules as far as Lat They were then of necessity left behind, and finally reached Magdala on the eve of our departure, enabling us, however, to obtain a supply of pure drinking water after the want of it for sixty hours

The water was obtained from the following sources —Lake Ashangi, measuring $3\frac{1}{2}$ miles by $2\frac{1}{2}$ miles, and 17 fathoms in depth, and possessing the peculiarity of having no outlet

The River Ayangua, rising at Lat, and said by some to be the source of the Tacazze

The Tellai River was crossed at Dildee

The Tacazze River was crossed at Miya

On the Wadela plateau the supply was obtained from the Santara, Gosho, Gashoss, and Fanta Rivers, running into the Jita.

The Jita River, about 2,500 feet below the Waddela and Dalanta plateau, was dry on the advance of the army on 4th of April, and nearly so on its return on the 23rd April The distance, in a bee line from one plain to the other, is not less than 3 miles, and the journey to accomplish by the King's road nearly 10 miles

Water was found on Dalanta plain in pools in the small valley. The formation here apparently was basaltic trap, while on the Waddela it was sandstone

The Bashilo River, 8 miles north of Fahla, running and knee deep, after several severe thunder showers, was the only water crossed deserving the name of a river It was the main source of supply to the army when encamped before Magdala

The water in the small native wells in the immediate vicinity of Magdala was unfit for any purpose, owing to the number of dead animals, &c , and the small supply obtained from the well dug by the troops, though clean, was of a peculiarly bitter taste A medical officer assured me however, that it was not injurious

Telegraph.—Lieutenant St. John's telegraphic operations have not come

under my observation beyond the Passes I can, however, bear testimony to their value, I may say the telegraphic communication has been simply invaluable, and it has not failed when most wanted

Engineer Park.—I have now to bring to His Excellency's notice that the engineer park, having had the advantage of being formed with great care in Bombay, under Captain Greig's directions, has always been enabled to comply with the requisitions made upon it It has fulfilled its purpose completely, and therefore calls for no further remarks

Captain Greig has expressed himself well satisfied with the exertions of his assistants—Lieutenant Saxton, R E, and Cornet Dalrymple, Assistant Field Engineers

It remains for me to bring to His Excellency's favorable notice the services of my Brigade Major, Captain Charles Goodfellow, V C, R E, Field Engineer, which have been so valuable to me by reason of his energy of character and experience in the conduct and management of Public Works

---

From LIEUTENANT-COLONEL WALLACE, *Commanding the First Division of Royal Artillery, to the Brigade Major, Royal Artillery, Abyssinian Expeditionary Force*

CAMP, RARA GUDDY,
May 23rd, 1868

SIR,—In accordance with instructions contained in your letter dated 11th instant, I have the honor to report as follows upon the elephant equipment of G-14 and 5th Battery, 25th Brigade, Royal Artillery

The four guns and carriages of G-14, 12-pounder breach loading Armstrong guns, were distributed in the following manner —

	Elephants
For each gun, 1 elephant,	4
„ carriage, 1 do,	4
„ limber and one wheel, 1 do,	4
„ pair of ammunition boxes and one wheel, 1 do,	4
For every three wheels of remaining eight, 1 do,	3
Total,	19

One of the latter elephants had but two wheels the load was made up by the sheers, tackle, &c

There are no means of weighing the several portions of the carriages, material, &c, but the following weights were given me at Poona Arsenal

I am, however, inclined to believe that the carriage is considerably heavier than noted —

	cwt	qrs	lbs		lbs
Gun,	8	1	0	=	924
Carriage,	8	2	14	=	966
Limber,	4	0	2	=	450
Wheels,	2	3	6	=	314
Ammunition box,	2	1	8	=	255

The cradle probably weighs about 150 lbs The elephant pads, gudalahs, &c , I am informed by Lieutenant Ouchterloney, weigh 500 lbs each set, consequently the weight of the several loads would be as under —

		lbs
Gun, elephant, gun,	924	
cradle,	150	
pads, &c ,	500	1,574
Carriage elephant, carriage,	966	
cradle,	150	
pads, &c ,	500	1,616
Limber, elephant, limber,	450	
wheel,	314	
cradle,	150	
pads, &c ,	500	1,414
Ammunition boxes, elephant, 2 boxes,	510	
wheel,	314	
pads, &c ,	400	1,322
Wheels, elephant, 3 wheels, pads, &c ,		1,442

With regard to the loading, it has been found impossible to use the sheers, it being difficult to get the animals under the fall, and remain quiet there Moreover, the nature of the soil is seldom such as to afford a good hold for the pickets The loading has, therefore, been effected as follows —In the case of the gun, one spar (with the carriage, two) is placed, one end resting on the ground, and the other on the cradle (the elephant being of course sitting), the breech screws being removed, handspikes are inserted into the bore at each end, and by these the gun is lifted up along the spar into its bed on the cradle by eight men To assist in this, a rope is attached to the gun at the trunnions, and passed over the cradle, and manned on the opposite side by three or four men , this tends to keep the load steady, while the men lifting get fresh purchase.

The carriage being heavier, 12 men are required to lift it, the arrangements are the same, except that two skids are used instead of one, up which to slide the load.

The limber is lifted in a similar manner (without skid) by men placed in the cradle, and a wheel laid upon it, and lashed securely

The ammunition boxes are carried, slung one on each side of the animal, with a wheel laid on top of the pad

The three wheels are slung one on each side, and one laid on the top

With regard to the time required for loading, the chief delay is in equipping the elephants with their gear and cradles as soon as this is done, the gun and carriage are loaded in two or three minutes. The other loads take longer, having to be lashed

Mortars—The 8-inch mortar with its bed requires two elephants, the weight being as follows those of travelling beds, cradles, pads, &c, being, as in the case of the Armstrong guns, approximately only —

	cwt	qrs	lbs
Mortar,	8	1	12
Iron (firing) bed,	7	2	0
Travelling (wooden) do,	1	2	0
Cradle,	2	1	0

The loads would be—

Mortar, elephant, mortar,	924	
Travelling bed,	168	
Cradle,	252	
Pads, &c,	500	1,844 lbs
Bed, elephant, iron bed,	840	
Travelling do,	168	
Cradle,	252	
Pads,	500	1,760 lbs

The weight of skids, implement boxes, handspikes, &c, are not known, but they form a good load for an elephant.

The powder has been carried on another elephant, and the shells on mules, four to each mule. The powder could likewise have been so carried.

The same objections to the use of the sheers exist with the mortars as with the guns The loading has been effected thus —

Two skids are placed (the elephant being seated) on the cradles, the other ends on the ground, these are kept at such a distance from each other by iron stays as will admit of the truckles of the travelling beds remaining on them, the tackle is attached to the bed, passed over the rollers or cradle, and manned on the opposite side of the animal by some 14 men, four men with handspikes heave the mortar on beds up to the skid, and the tackle being then hauled on, the load is run up into the

cradle in a few seconds, to prevent the pad or bed being displaced by running up the load, a third skid is placed on the hauling side against the cradle, and thus check the tendency of the cradle to come over with the haul, and supports the gear, and keeps it in place The delay in preparing the elephants is the same as with the guns

The unloading is performed under the same arrangement with both description of pieces, though with the guns it is a much easier process than when loading, and frequently one skid only has been used with the carriage

For marching in ordinary countries, the equipment now used is, I think all that can be desired the only alteration I would suggest is, that curled hair should be used, for saddles, instead of coir, for stuffing the underpad, which should be somewhat thicker than that now used

The skin of the elephant is so originally tender that it easily becomes galled, and serious galls and sores ensue from the friction, as well as the pressure of the heavy weight carried, and which have been on their backs at times from 12 to 20 hours without interruption

In a mountainous country, such as that recently travelled over, I would propose that the pads be fitted with breechings and breast-pieces, as the rope now used for this purpose, and which in the one case is pulled tight under the tail, and in the other under the throat, has caused very severe galls and sores to those parts, notwithstanding that a piece of chafing leather was placed between the rope and skin Moreover, in ascending, the strain caused by the weight being thrown back, acted very detrimentally on the respiration, almost choking the elephant

To remedy this defect, probably an arrangement like a horse-collar might be applied Pads are also needed to place under the elephants' knees and elbows, when sitting down to be loaded on rough and stony ground

I consider that it would be an improvement if the pads were attached and secured in the same manner as the cradles, that is, by being secured from the sides, under the belly, instead of by ropes passing completely round and over the animal The objection to the latter method is, that if the ropes are found to be loose, either from carelessness on the part of the mahout, or the tricks of the animals, they cannot be adjusted without removing the load, whereas, under the other arrangement, the ropes can be drawn tight as in the girths of a saddle.

The cradles, &c, supplied to G-14 were somewhat slight, having been intended for a 6-pounder battery The bed for the gun had to be cut to receive the larger circumference of the 12-pounder gun

---

From LIEUT-COLONEL MILWARD, *Royal Artillery, to Brigadier General Pétrie, Commdg Royal Artillery, Abyssinian Field Force*

CAMP BELAJO,

May 8th, 1868

SIR,—In compliance with the orders of His Excellency the Commander-in-Chief, I have the honor to submit the following report on the equipment, condition, and services of the Steel Mountain Batteries attached to the division of Artillery under my command

On my arrival at Zoulla on the 4th January, I found that the equipments, which had arrived from England some weeks previously in excellent condition, had been taken over by the officers commanding the 3rd and 5th Batteries, 21st Brigade, and that some progress had been made towards fitting the pack-saddles and mounting the batteries on mules, which had been supplied from those in charge of the Transport Train I attribute the rapid progress made in the fitting out of these batteries in a great degree, to the exertions of Lieutenants Nolan and Chapman, and the few non-commissioned officers under their command These officers, with such small assistance as the exigencies of the service could afford at that most difficult period of the campaign, had disembarked, unpacked, and arranged the whole of the equipments of two batteries They had procured and taken charge of 200 mules, and on the arrival of the batteries from Bombay, little was left to the Commanding Officers but to make the final arrangements to complete their batteries in a condition to take the field

The mules supplied were all taken from those lately arrived from Suez,—for the most part Spanish. The manner in which these animals have done their work proves that they were of good quality, and only require constant care, good feeding, and careful packing, to ensure their thorough efficiency I may, however, take this opportunity to observe that the very large Spanish mules do not keep their condition or carry their loads as well as those of moderate size I have invariably observed that a few days of short rations threw them out of condition, which they did not recover as rapidly as could be desired.

Being of opinion that the scale of equipment laid down in the printed list supplied with the batteries was quite insufficient, I obtained your permission to draw up a proposal for an increase in the number of mules and the quantity of ammunition to be carried with each battery. I accordingly submitted the following as a sufficient scale of equipment to take into the field, and having received in due course the approval of His Excellency the Commander-in-Chief, it has been adopted throughout the campaign —

MULES.

Guns and carriages	Ammunition and rockets	Spare carriage	Wheels	Forge	Artificers tools	Material for repairs	Mounted N. C. Os and Trumpeters.	Spare	TOTAL
18	61	1	2	1	1	6	3	20	113

AMMUNITION.

Projectiles.	In ammunition boxes	In reserve boxes	TOTAL	
Common shell,	168	0	168	604
Shrapnell „	144	32	176	
Double „	120	48	168	
Case shot,	72	20	92	
Rockets,	72	80	152	

The loads of ammunition were found to be too heavy to be carried conveniently, and it was found desirable to remove one shell from each box. It was also found necessary to reduce the weight of the rocket-cases by removing four from each, and to reduce the carriage-load by the weight of the wheels, which were placed on a separate mule. The scale of entrenching tools was quite inadequate for the probable requirements, and sufficient provision had not been made for the carriage of small articles not easily enumerated, but none the less necessary in the equipment of a battery. Boxes were made for the purpose, which were fitted to be carried on the top of certain loads, and arrangements were made to carry a sufficient supply of entrenching tools. These altogether necessitated a larger number of mules than was originally contemplated,

and, with the somewhat large proportion of spare animals necessary to meet the requirements of so peculiar a campaign, brought up the total number to 113.

In order to familiarize officers and men with the guns and ammunition entrusted to them, practice to a small extent was carried on at Zoulla, during which I found that firing with double shell had a tendency to shake the wheels to an extent which might be found inconvenient in actual service. I accordingly constructed wooden mortar beds, which were found to answer the purpose admirably. These were hastily constructed, and were not of the best materials or dimensions; but I would recommend that, in all future batteries of 7-pounder rifled guns, properly constructed carriages of this nature should form part of the equipment.

The practice carried on at Zoulla was sufficient to show the officers and men that the guns were good and effective beyond what they could have anticipated. They applied themselves to mastering the details of drill and the movements of the batteries with the utmost zeal and with the best results. I cannot give too much praise to officers and men of garrison batteries quite unaccustomed to the work, for the rapid progress made, and for the degree of efficiency obtained.

The strength of the batteries being quite insufficient, 1 Sergeant, 2 Corporals, and 25 Privates of the 4th (King's Own) Regiment were attached to each battery; these men have since acted as drivers, and have been found most useful and efficient.

After careful consideration, I decided on the following distribution of the mules: this arrangement has been maintained throughout, and has been found to work well:—

Sub division	No 1	No 2	No 3	No 4	No 5	No 6	REMARKS
Gun,	1	1	1	1	1	1	A small proportion of spare material for artificers will be carried in the mail boxes on the wheel mules
Carriage,	1	1	1	1	1	1	
Wheels,	1	1	1	1	1	1	
Ammunition,	4	4	4	4	4	4	
D shell	1	1	1	1	1	1	
Rockets,	1	1	1	1	1	1	
		Spare wheels	Spare carriage	Spare cradle, &c	Spare wheels	Forge	
Miscellaneous stores,	1	1	1	1	1	1	
	10	10	10	10	10	10	

RESERVE

15	mules,	8 double shell each
5	„	16 rockets „
2	„	16 shrapnel „
1	„	20 case shot
5	„	Spare material
1	„	Powder in cases
1	„	Forges, tubes, &c.
1	„	Veterinary stores

The mules for the reserve will be furnished in equal proportions by the divisions The reserve will be picked separately under the Conductor of Stores The mules will be picketted with their divisions

On the 27th January, the A Battery, under Lieutenant-Colonel Penn, marched from Zoulla, reaching Senafé on the 31st January, Addigerat on the 5th February, and Antalo on the 20th February The excellent manner in which the march was so far completed left nothing to be desired Antalo was reached without a casualty No load was even displaced on the road, there were no galls, no sore backs, no sickness From Addigerat to Antalo the battery was attached to the advance brigade, the road, always very hilly and rough, had been only partially made in many places, and could only have been traversed with great difficulty by animals less perfectly laden No difficulty however was found which was not overcome by the energy and intelligence of officers and men

At Antalo, His Excellency the Commander-in-Chief having expressed a desire that a longer range might, if possible, be obtained with the double shell, I caused a trial to be made with 4-oz cartridges, and with them I obtained a range of 1,450 yards without apparent distress to gun or carriage I therefore made up a few of these cartridges, which were afterwards used with good effect

Wooden tangent scales were also made for use, instead of the quadrant, when firing at high angles. These were only roughly constructed by the battery artificers, but they were found useful, and I would recommend their adoption in all future equipments

Marching from Antalo on the 12th March, the A Battery accompanied the advance throughout—the almost insuperable difficulties of the road were surmounted without accident or loss—the great ravines of the Tacassie, the Jiddah, and the Bashilo were crossed without casualty, that of the Jiddah with the advanced guard of the army, over a track

which might well have been considered impassable, but the only damage was the loss of a foresight, broken in the fall of a gun with the mule which carried it, over a cliff

Arriving before Magdala on the 10th April, this battery found itself in action with the enemy On this occasion 19 rounds per gun were fired at ranges varying from 450 to 1,800 yards with shrapnel and common shell, the practice was excellent, and caused heavy loss to the enemy. The fuzes acted well, the ranges were changed with ease, and the successive changes of position of the battery were made with the greatest ase and rapidity I observed with one gun a slight tendency, after firing a few rounds rapidly, to jamming of the shell in the bore This however was at once removed by a damp sponge, and I would suggest that these should be used invariably when rapid firing is considered necessary.

The B Battery, under command of Captain Twiss, did not leave Zoulla until the end of February, and in the mean time the mules had been almost constantly engaged in heavy transport duty between Zoulla and Senafé Leaving at so late a date, the battery was called upon to march rapidly to the front, and it reached Antalo without a halt. From Antalo to the front, the difficult marching did not afford any opportunity for recruiting, and the mules are not in such high condition or so fine in appearance as those of A Battery, they have however carried their loads well, and no accident involving loss of stores has occurred. B Battery did not cross the Bashilo until the afternoon of the 10th April, and was not therefore engaged on that day, but having been brought to the front on the following morning, I had the honor of commanding both batteries together, on the 13th April, at the capture of the fortress of Magdala On this occasion, eighteen to twenty rounds per gun were fired at ranges from 1,300 to 1,500 yards, common and double shell only being used, 15 rounds of the latter were fired with 4-oz charges at a range of 1,400 yards, and carried well to that distance The common shells were used in shelling the defences of the gate of Magdala, and the precision of the fire could not be excelled. The shells were observed to burst regularly and without failure No difficulty was experienced in loading or in boxing and fixing the fuzes, and that the intended effect was produced, was manifest from the fact that the defenders of the gate were observed to retreat in large numbers, some time before the advance of the assaulting party was ordered.

The storming party having secured an entrance, one battery was advanced, and, at my suggestion, one gun, with a small supply of ammunition, was carried by the gunners up the steep ascent through the narrow entrance, and brought into action within the fort. No further occasion for its services arose, but I would venture to point to this service as one of vast utility in the future of mountain guns. It will be a rare occasion when the ascent to a breach will offer greater difficulties than those of the ascent to the gate of Magdala.

On the 10th and 13th April, 25 Hales' rockets were fired; they acted well, and I considered them in all respects good and efficient.

Having reached Ashangi on the return march, I obtained the permission of His Excellency the Commander-in-Chief to fire a few rounds over the lake, with a view to observe the action of the fuzes in ricochet, and to afford foreign officers and others an opportunity of witnessing the effect of the bursting of the different kinds of shells.

It is with much gratification I have to report that the result was eminently satisfactory, confirming my opinion as to the perfect serviceability of the fuzes, establishing the fact that they are not extinguished on striking the water, and demonstrating what a formidable projectile can be thrown from a miniature piece of ordnance, with an insignificant charge of powder.

In conclusion, I beg to record my opinion that the value of the 7-pounder steel mountain guns, with their projectiles and equipments, is successfully established, that in the hands of good gunners, with batteries of sufficient strength, and mules in good condition, they are capable of carrying into any country, which can be traversed by an army, an artillery fire far more effective than any which has been hitherto attained in mountain warfare.

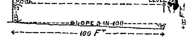
Correspondence.

The Editor acknowledges, with thanks, the receipt of the following papers —The Normandy Condenser—Kurrachee Harbour Works—Bombay and Baroda Railway Bridges—Markunda Tree Spurs—G T Survey Report for 1866-67—Revenue Survey Reports for 1866-67—Notes on the Mississippi Report—Bastier's Patent Chain Pump—Demolition of Fort Kotaha—Note on Navigation Canals—Experiments on Dharwar Timber —Problem in Pendulums—Memoranda of Leveling Operations in the G T Survey—Trellis Work in Chunam—Note on Timber Measurement —Note on Steam Rollers—The New Lahore Church—Chakrata Hill Road—Problem in Pendulums—Motion of Water in Canals—Distribution of Canal Water—The American Tube Well—Motion of Running Water —The Dewan-i-am Barrack—Spurs used on the Damooda—Tanner's Exhaust Fan—Experiments on Dharwar Timber—Rice Cultivation in Portugal—Irrigation Canals of Italy—Irrigation Canals of Spain—Rope Bridge over the Chenab—Iron Sluice Gate for Reservoirs—Navigation of the Seine—Motion of a Train on Inclines—The Surat High School—The Abyssinian Railway—Notes on Carriage—Addis's Improved Cart—Stone for Kurrachee Harbor Works—Theory of Carriage—New Barracks, Saugor—Irrigation in Sind—Purification of Drinking Water—N W P Irrigation Revenue Report for 1866-67—Stone Trusses in Central India.

DE LISLE'S CLINOMETER

To the Editor

Dear Sir,—The De Lisle Clinometer, "lately described in the Indian Professional Papers" is a combination of the ordinary French "Reflecting Level" (described in all Surveying Manuals) and a Clinometer It appears to me that the reflecting level alone will be



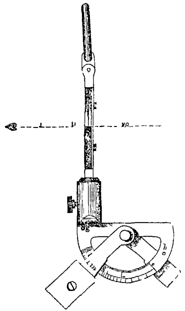
quite accurate enough for ordinary road gradients, which are oftener laid out by

slope than by the angle of inclination (3 in 100, 4 in 100, &c, &c) If now the vane, as in sketch, is set on its staff as many feet below the height of the observer's eye as the inclination per chain, the level will give the point required with as great accuracy as the clinometer, and without the trouble of adjusting the latter. The level is moreover a very easily constructed instrument

Yours faithfully,

TALBOT HAMILTON

GOONA, CENTRAL INDIA,
February 3rd, 1868



In reference to the above instrument, the diagram above should have been given with Col De Lisle's letter to the Editor in Vol IV, *see* p viii, first line —[ED]

To the Editor.

DEAR SIR,—Your first volume has only been in my possession lately, since I returned to India.

In it I see a perspective engraving of the Lahore Station—will you permit me to remark, that was engraved either from *my* original drawing in the office at Lahore, or from a photograph taken from that drawing, the duplicate of which I have now.

The original drawings were all made by me, even to the details in full size for every moulded and cut brick, and the sliding gates were suggested and designed by me also. The flat roof originally ordered, I never approved of, and it was subsequently altered But the original design for the central gothic window was unfortunately changed for the present ugly one

Your obedient servant,

JOHN CALVERT, M INST C E, F G S

WAR OFFICE,
4th September, 1868

To

MAJOR MEDLEY, R E,
Principal, Thomason College,
Roorkee

SIR,—I would call your attention to an interesting paper by Lieutenant Innes, R E, on the subject of "Damp in Powder Magazines as affected by Ventilation," which has been published in Volume XVI of the Professional Papers of the Corps of Royal Engineers; and, as it is probable that important information on the same subject might be obtained from Officers who have had experience of the Ventilation of Magazines in India, I would suggest that you should invite, or collect, for publication in the Professional Papers, remarks on this subject from Officers of the Corps serving in India

I would be glad to be furnished with the results of any observations which might be useful in adapting the details of construction of bombproof buildings to suit the requirements of particular climates

I have the honor to be,
SIR,
Your obedient Servant,
E. O FROME, *Major-General,*
Inspector General Engineers.